

US009958976B2

(12) **United States Patent**  
**Endo et al.**

(10) **Patent No.:** **US 9,958,976 B2**  
(45) **Date of Patent:** **May 1, 2018**

(54) **ELECTRONIC DEVICE**

(2013.01); *H01L 51/5237* (2013.01); *G06F 2203/04102* (2013.01); *H01L 27/3211* (2013.01); *H01L 27/3251* (2013.01); *H01L 2251/5315* (2013.01); *H01L 2251/5338* (2013.01)

(71) Applicant: **Semiconductor Energy Laboratory Co., Ltd.**, Kanagawa-ken (JP)

(72) Inventors: **Akio Endo**, Kanagawa (JP); **Shigeru Onoya**, Kanagawa (JP); **Masaaki Hiroki**, Kanagawa (JP)

(58) **Field of Classification Search**

CPC ..... G06F 1/1615  
USPC ..... 361/679.21  
See application file for complete search history.

(73) Assignee: **Semiconductor Energy Laboratory Co., Ltd.** (JP)

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days. days.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,353,529 B1 3/2002 Cies  
6,842,338 B2 1/2005 Iredale  
(Continued)

(21) Appl. No.: **15/443,670**

(22) Filed: **Feb. 27, 2017**

FOREIGN PATENT DOCUMENTS

JP 2003-174153 A 6/2003

(65) **Prior Publication Data**

US 2017/0177130 A1 Jun. 22, 2017

*Primary Examiner* — Jerry Wu

**Related U.S. Application Data**

(63) Continuation of application No. 14/629,990, filed on Feb. 24, 2015, now Pat. No. 9,588,549.

(74) *Attorney, Agent, or Firm* — Husch Blackwell LLP

(30) **Foreign Application Priority Data**

Feb. 28, 2014 (JP) ..... 2014-039372  
Oct. 28, 2014 (JP) ..... 2014-218932

(57) **ABSTRACT**

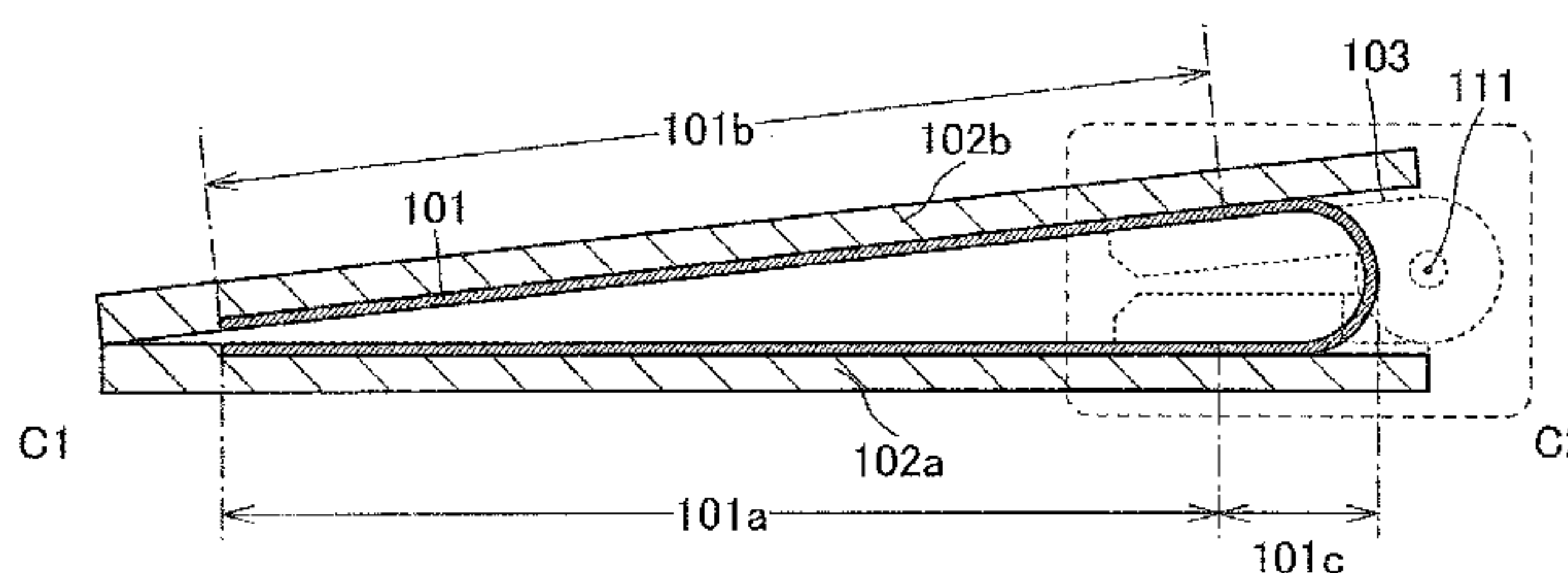
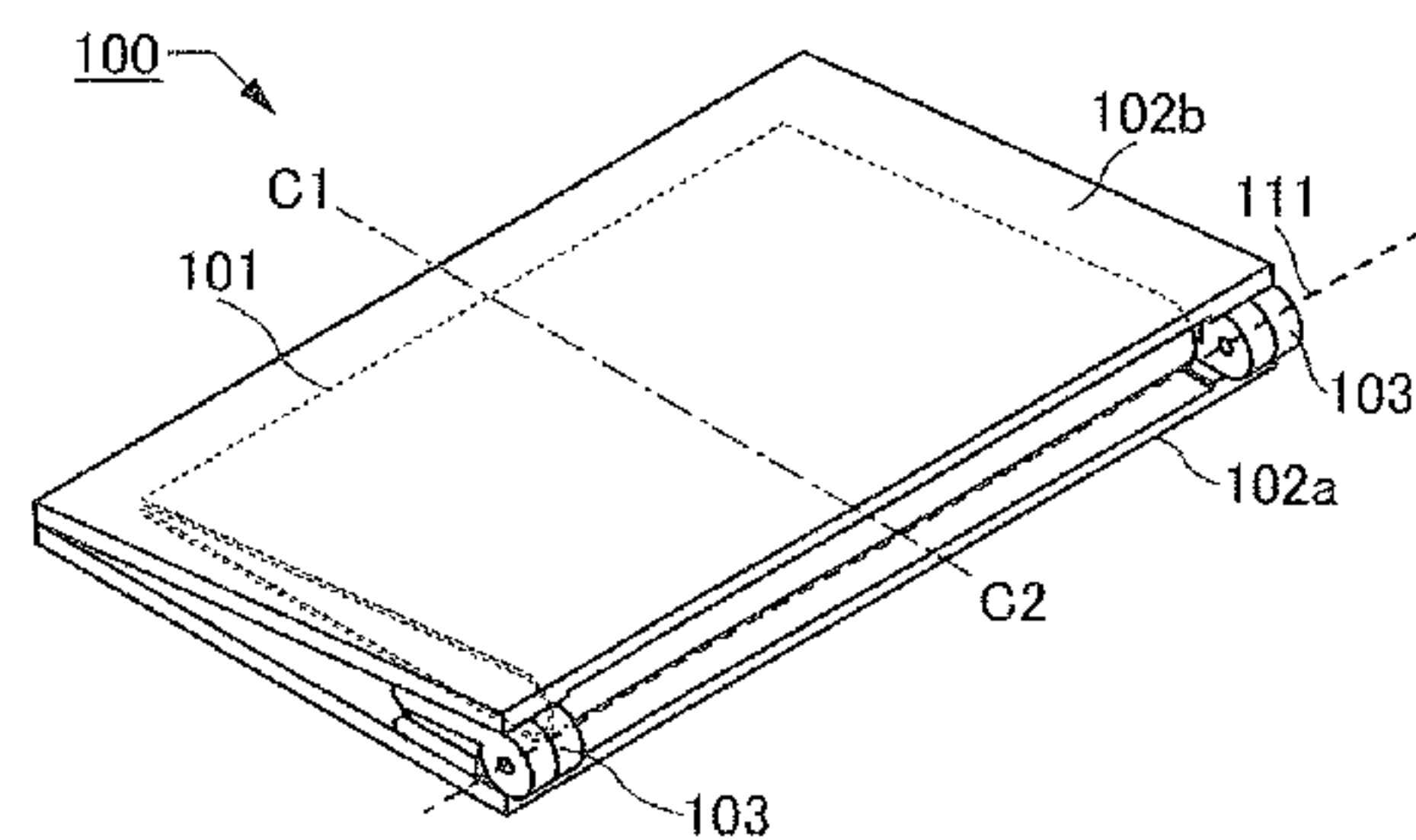
Provided is an electronic device with high portability and/or high browsability. The electronic device includes first and second support bodies, a first hinge, and a flexible display panel. The first hinge has a first rotation axis and connects the first and second support bodies to each other, and the first and second support bodies are capable of relatively rotating on the first rotation axis. The display panel includes at least first and second portions supported by the first and second support bodies, respectively; the first rotation axis and a first plane including the display surface overlapping with the first portion or a second plane including the display surface overlapping with the second portion are parallel to each other; and each of a distance between the first rotation axis and the first plane or the second plane is greater than zero.

(51) **Int. Cl.**  
*H05K 7/00* (2006.01)  
*G06F 3/041* (2006.01)

(Continued)

(52) **U.S. Cl.**  
CPC ..... *G06F 3/0412* (2013.01); *G02F 1/1368* (2013.01); *G02F 1/13338* (2013.01); *G02F 1/133305* (2013.01); *G06F 3/044* (2013.01); *H01L 27/323* (2013.01); *H01L 27/3244*

**16 Claims, 27 Drawing Sheets**



- (51) **Int. Cl.**  
*H01L 51/52* (2006.01)  
*H01L 27/32* (2006.01)  
*G06F 3/044* (2006.01)  
*G02F 1/1333* (2006.01)  
*G02F 1/1368* (2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

8,415,208	B2	4/2013	Takayama et al.	
D719,542	S *	12/2014	Lee .....	D14/138 AB
2010/0016038	A1	1/2010	Demuynck et al.	
2010/0277448	A1	11/2010	Okamoto et al.	
2014/0042293	A1	2/2014	Mok et al.	
2014/0375660	A1	12/2014	Tamaki	
2015/0016126	A1	1/2015	Hirakata et al.	
2015/0023030	A1	1/2015	Tsukamoto	
2015/0023031	A1	1/2015	Endo	
2015/0035777	A1	2/2015	Hirakata et al.	
2015/0055286	A1	2/2015	Eguchi	
2015/0062525	A1	3/2015	Hirakata	
2015/0062927	A1	3/2015	Hirakata et al.	
2015/0103023	A1	4/2015	Iwaki	
2015/0177789	A1	6/2015	Jinbo	
2015/0229844	A1	8/2015	Yamazaki et al.	
2015/0233557	A1	8/2015	Aoyama et al.	
2015/0248149	A1	9/2015	Yamazaki et al.	
2015/0250038	A1	9/2015	Sakuishi et al.	
2015/0261259	A1	9/2015	Endo et al.	

\* cited by examiner

FIG. 1A

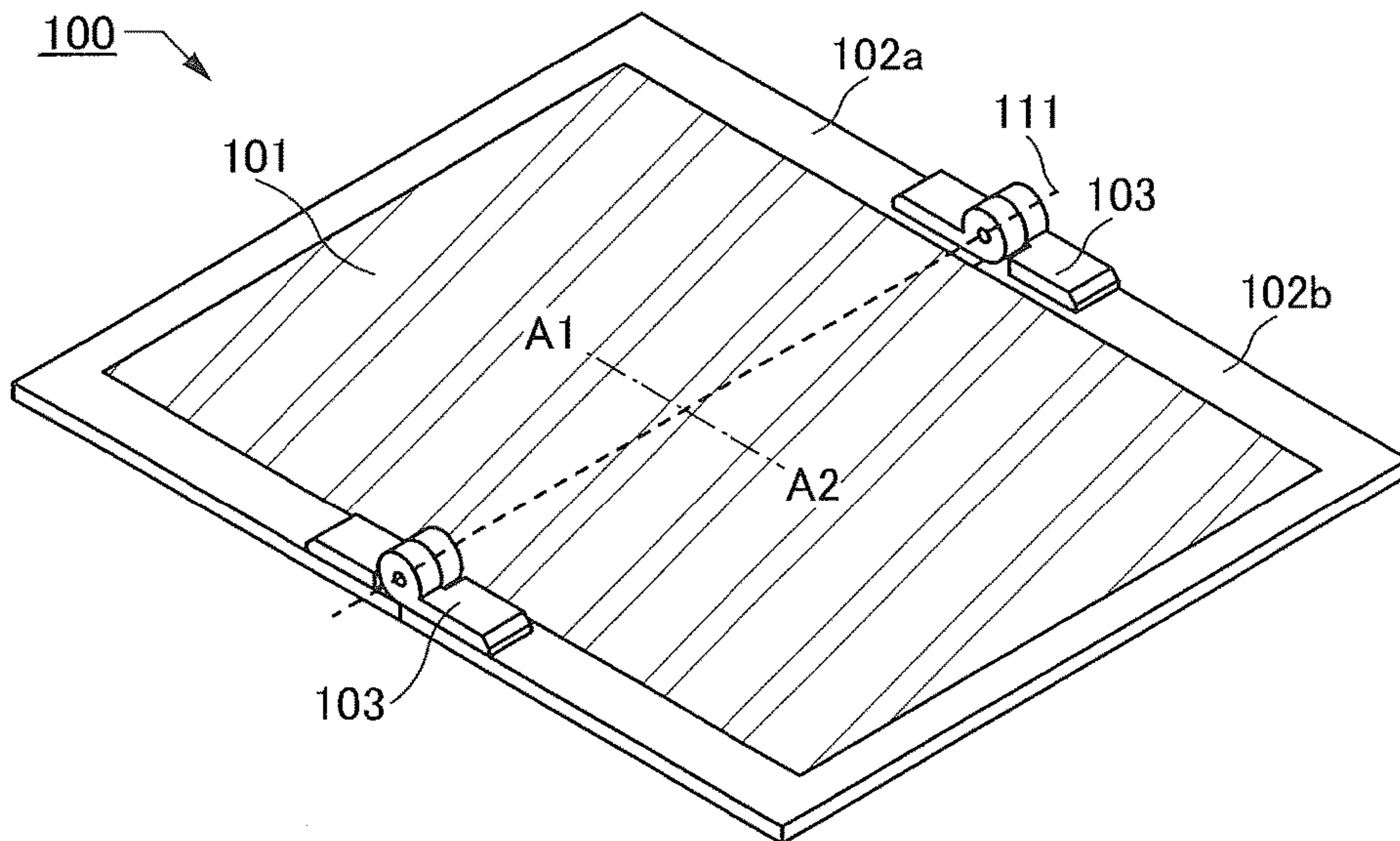


FIG. 1B

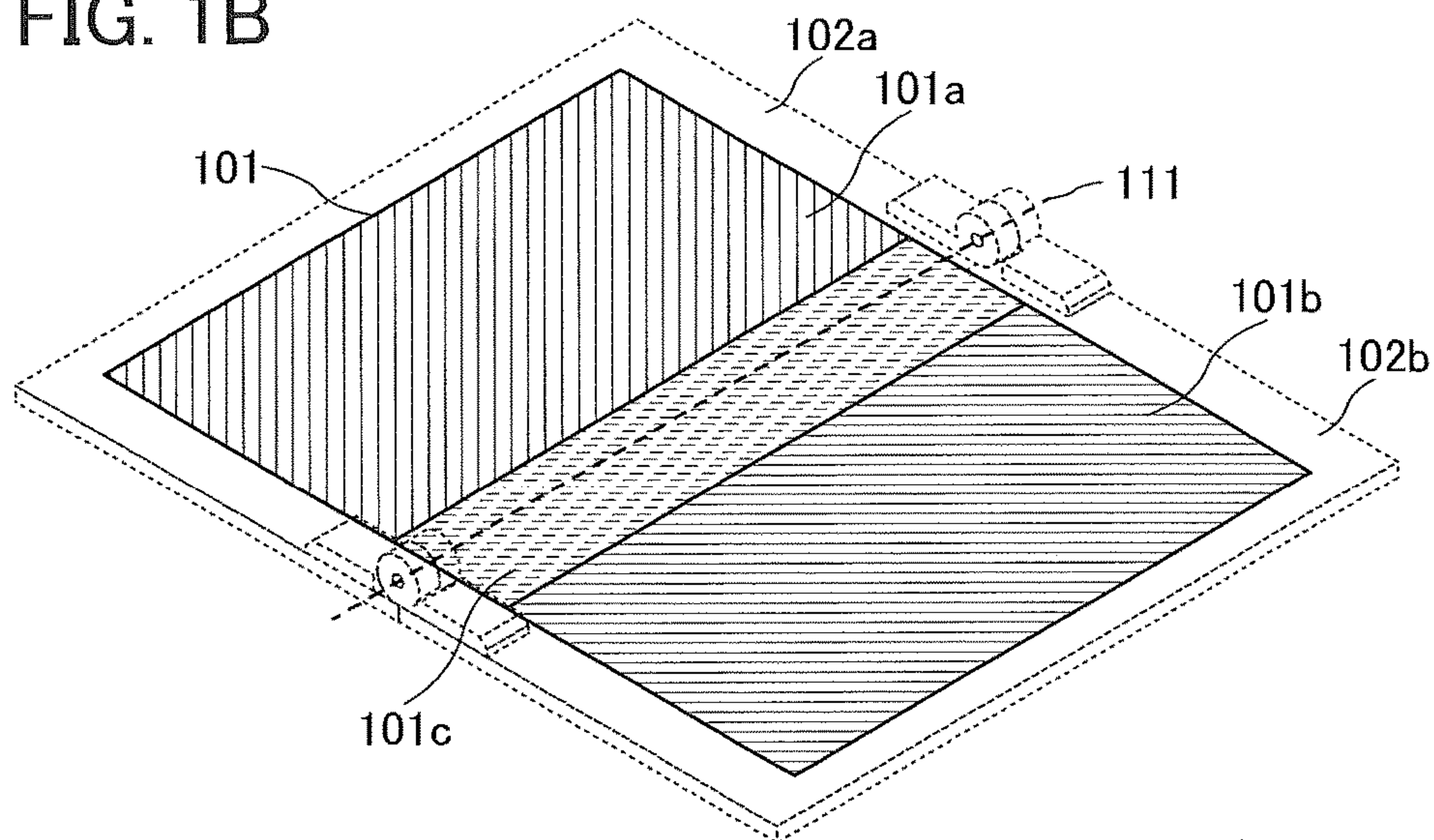


FIG. 1C

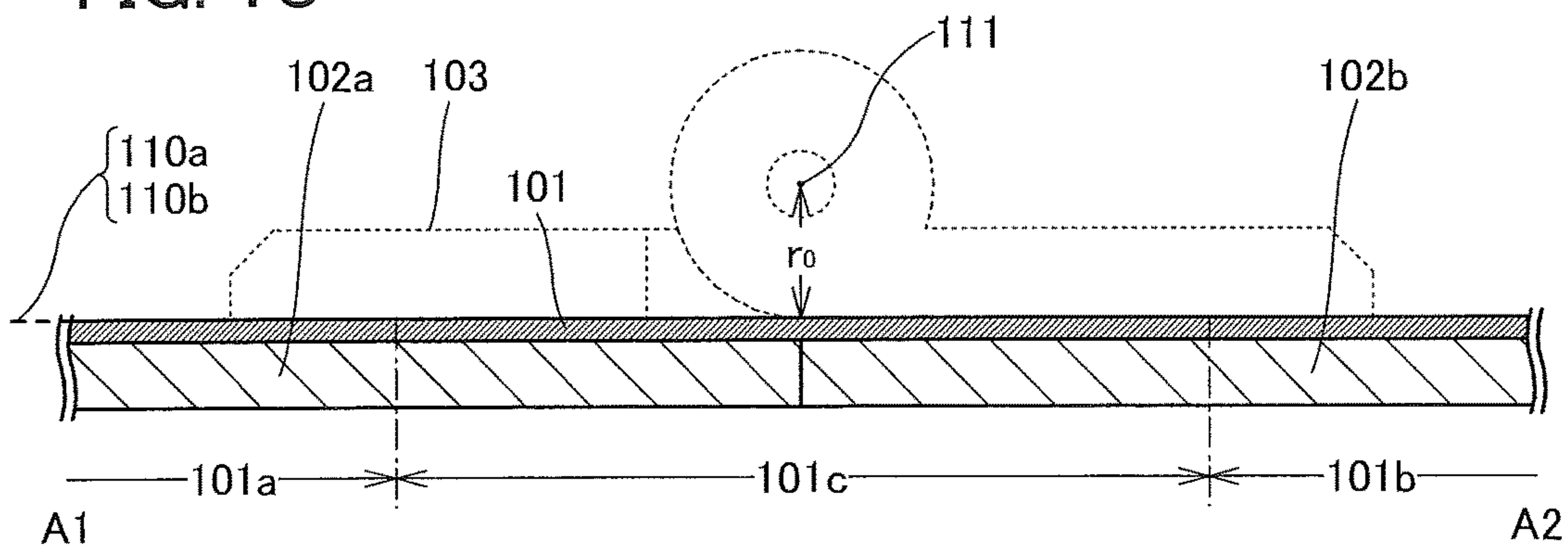






FIG. 3A

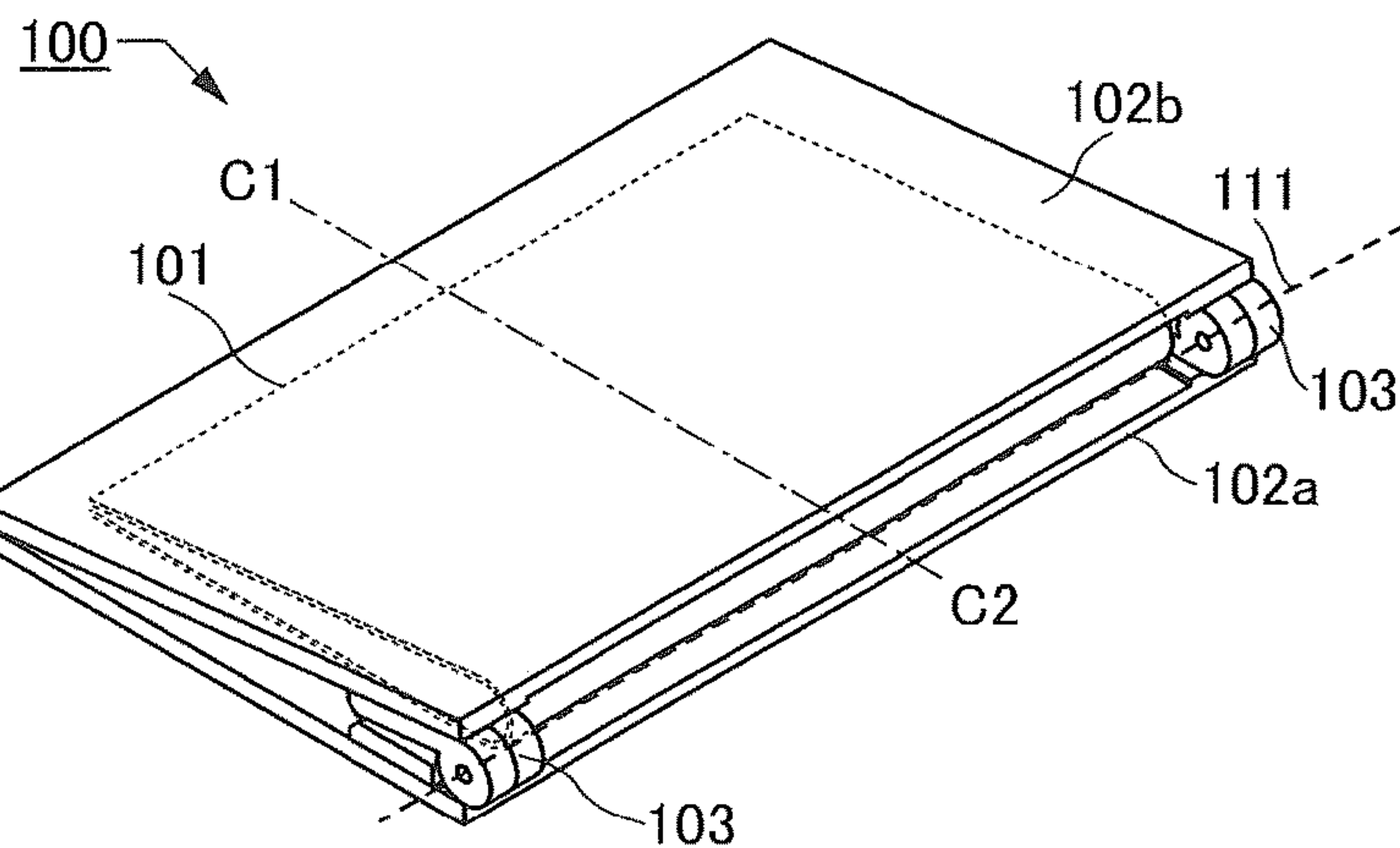


FIG. 3B

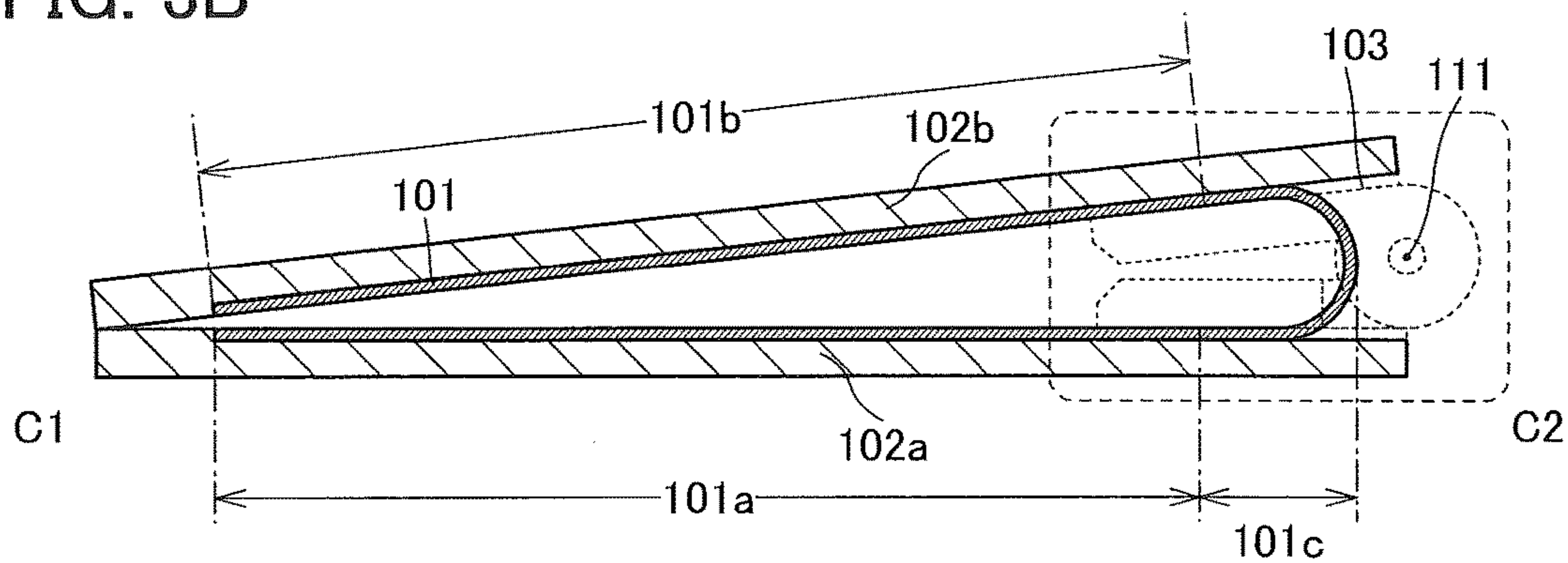


FIG. 3C

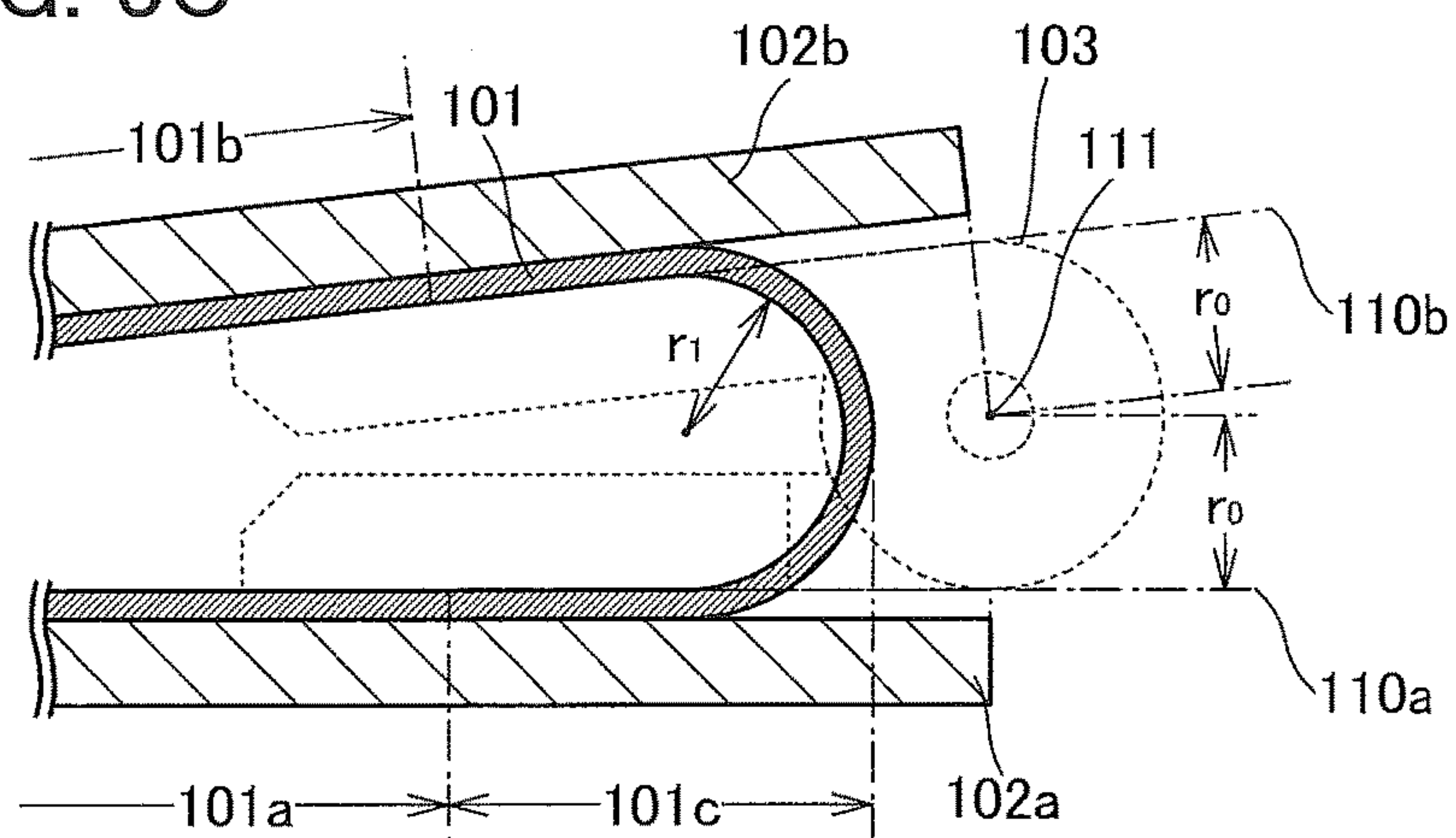


FIG. 4A

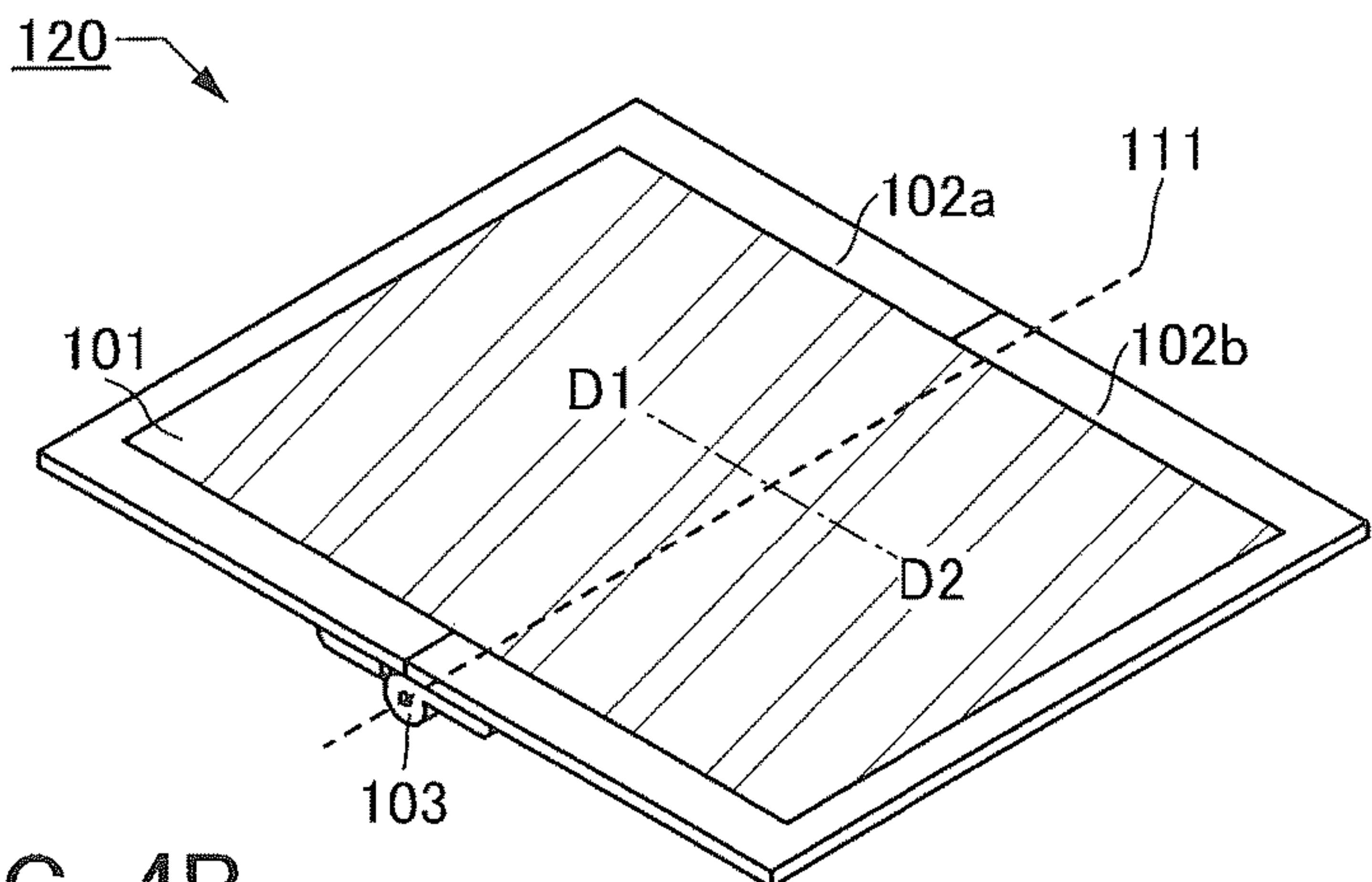


FIG. 4B

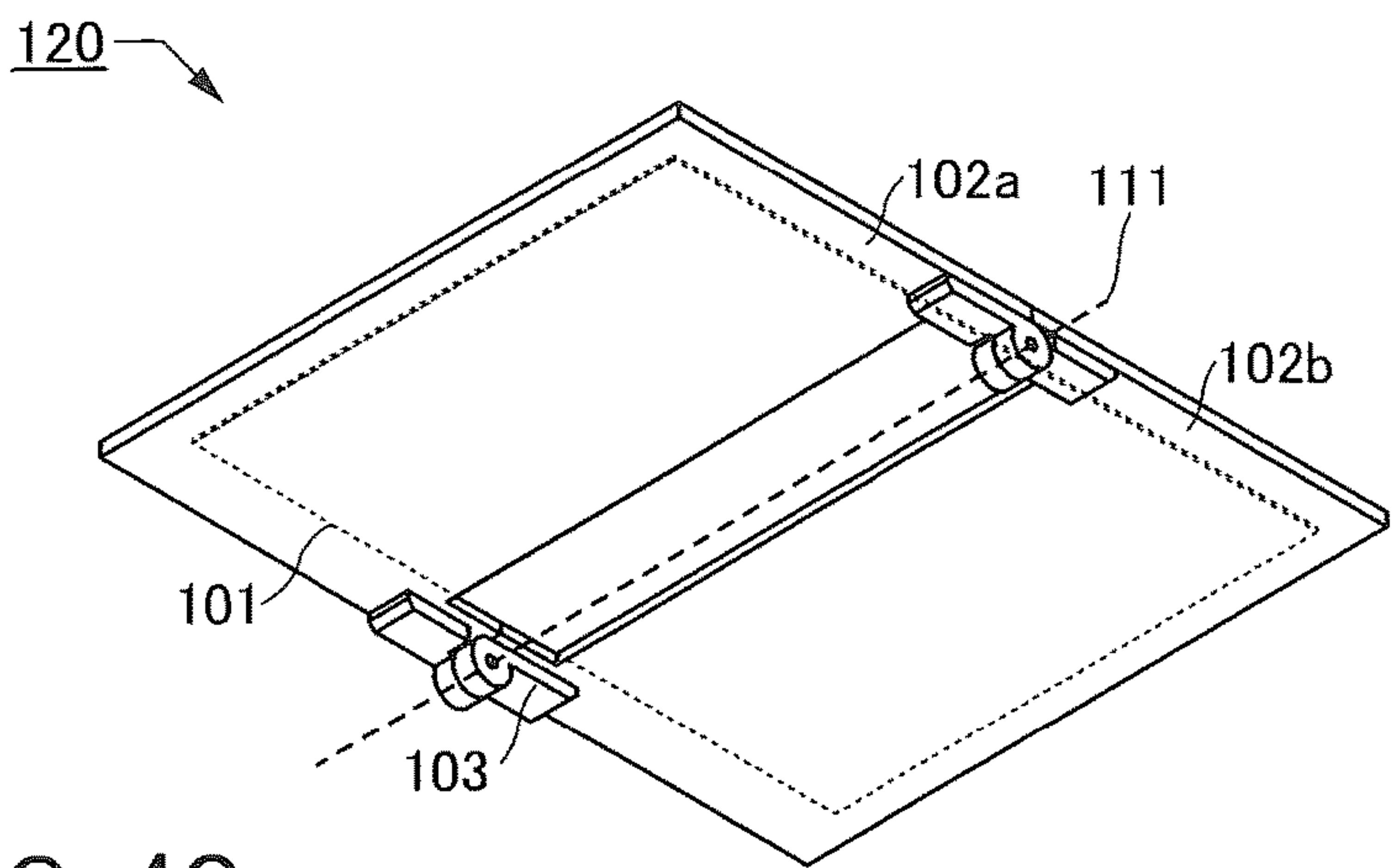


FIG. 4C

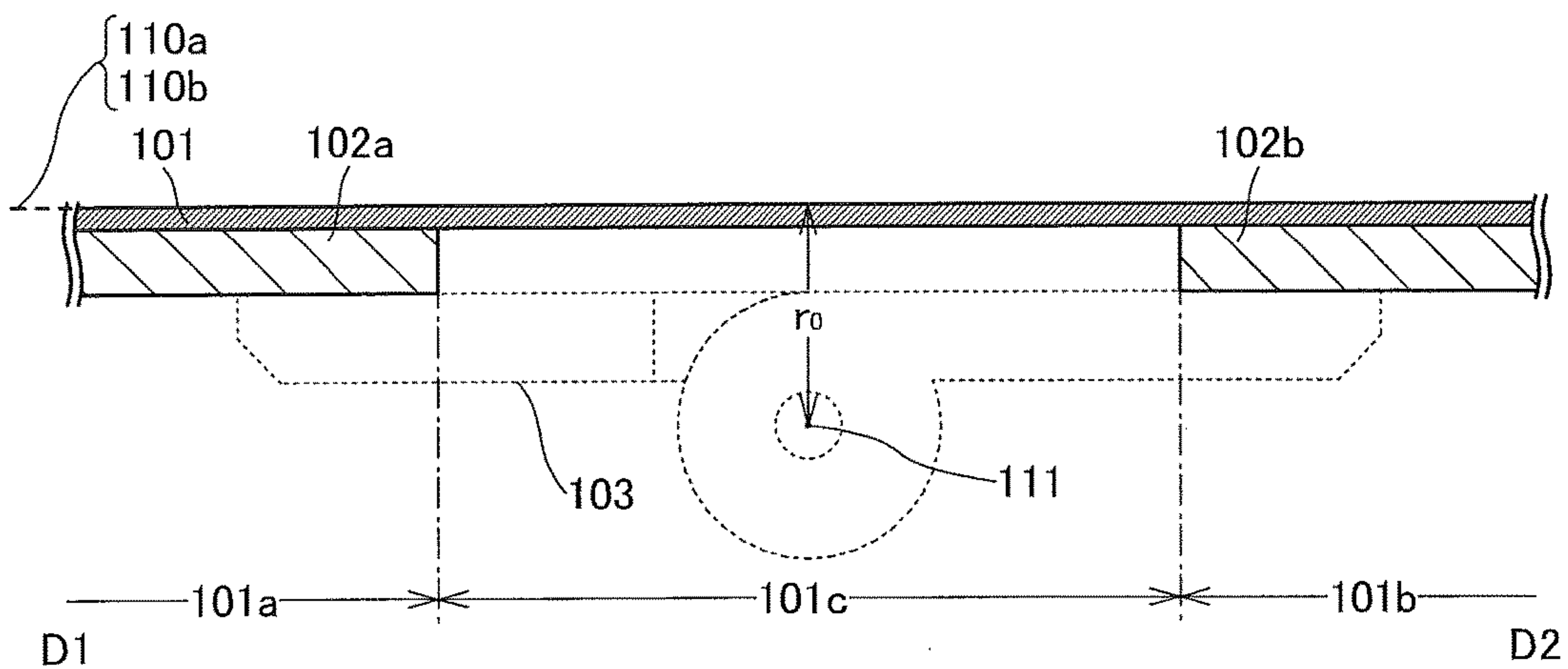






FIG. 6

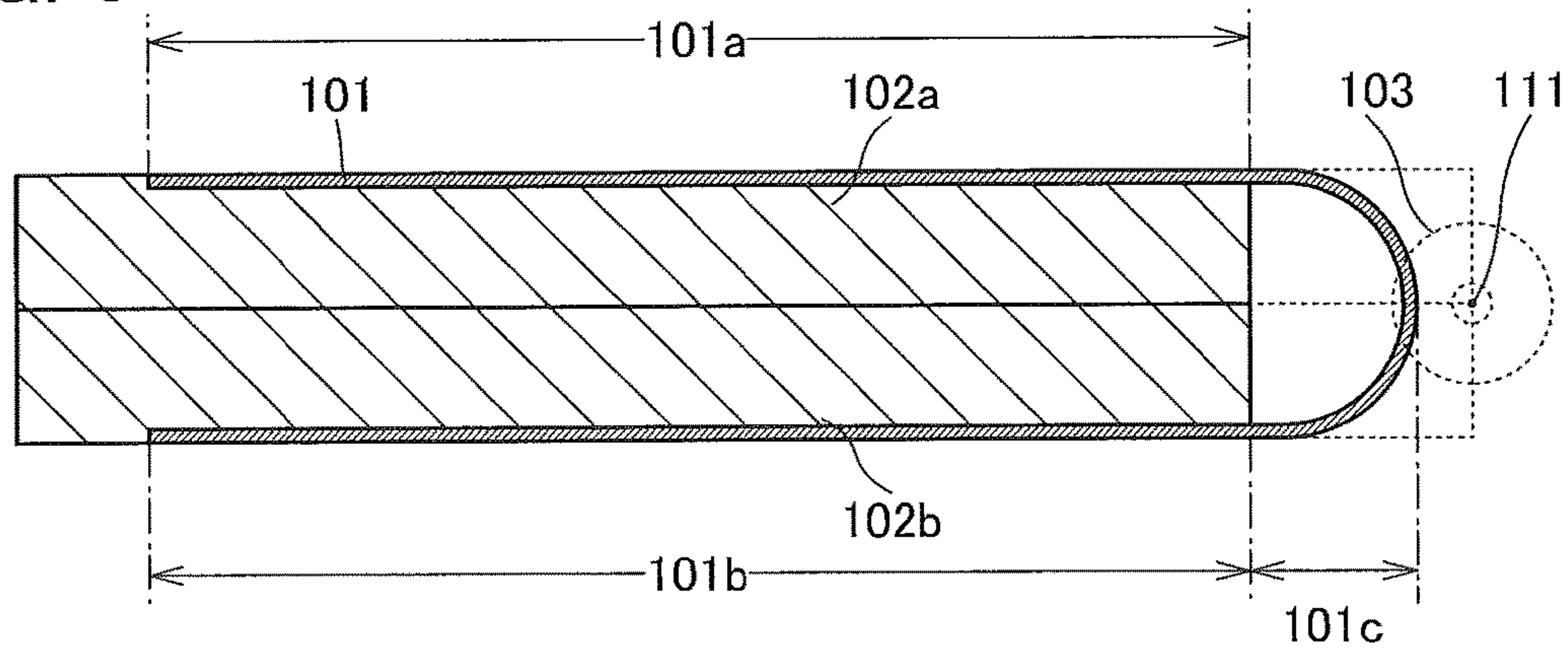




FIG. 7A

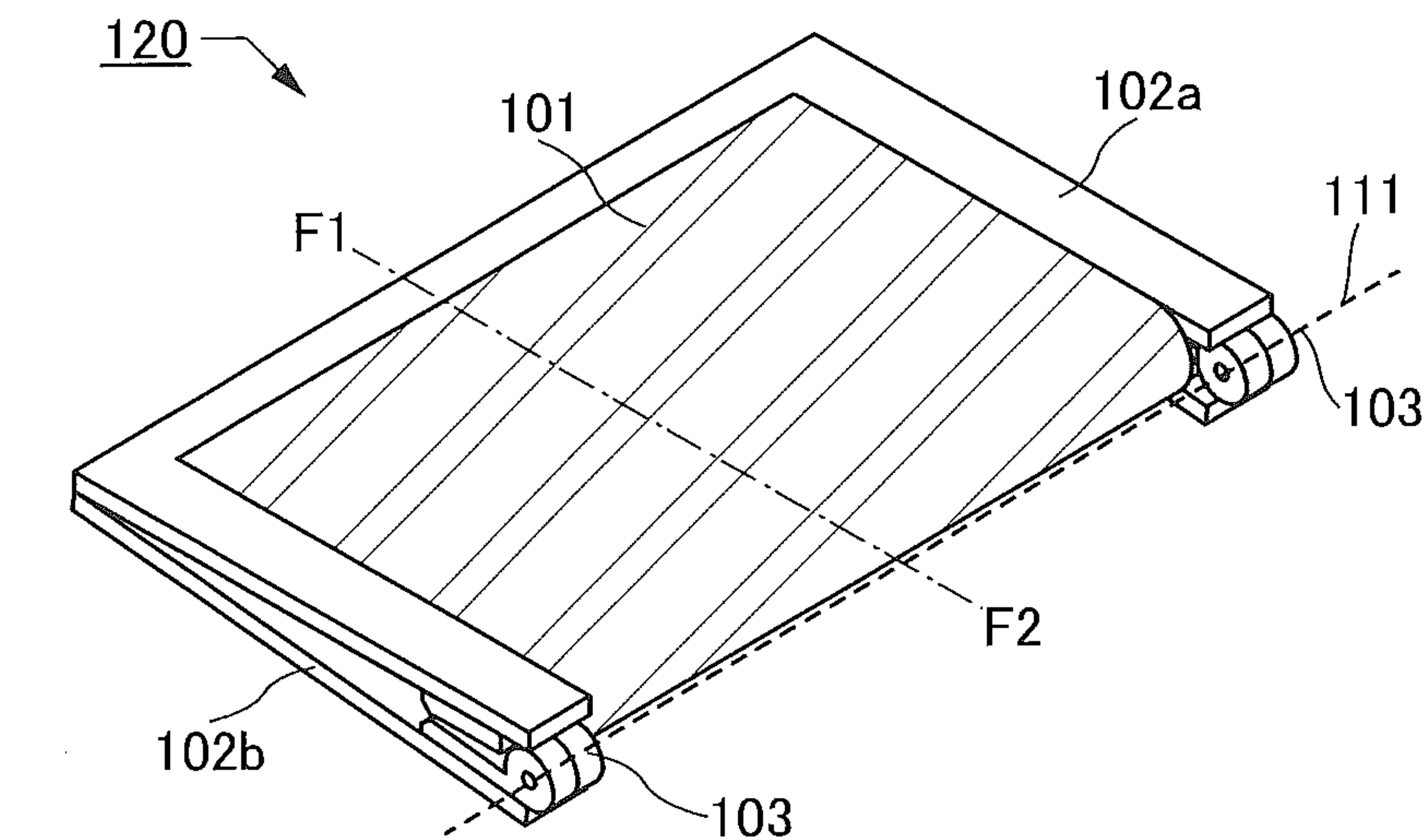


FIG. 7B

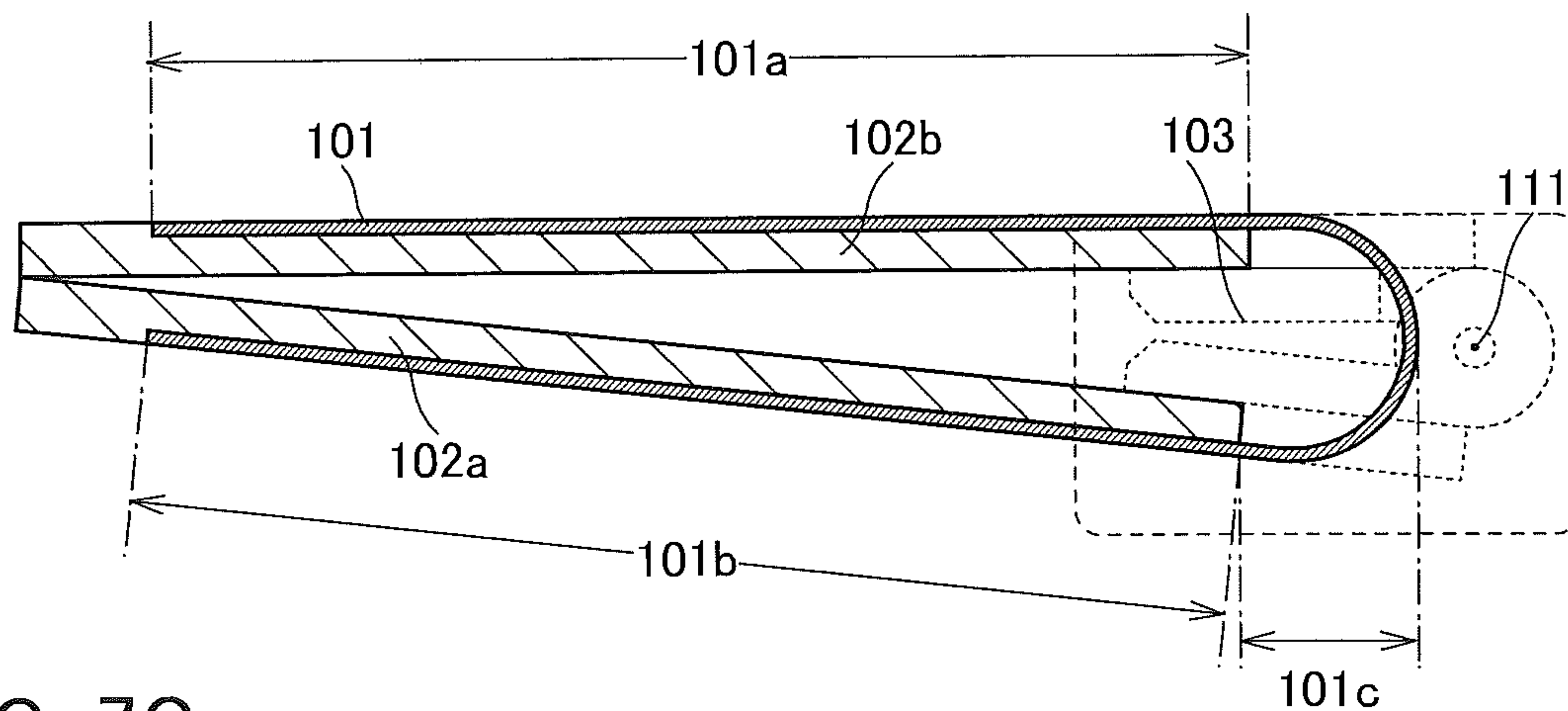


FIG. 7C

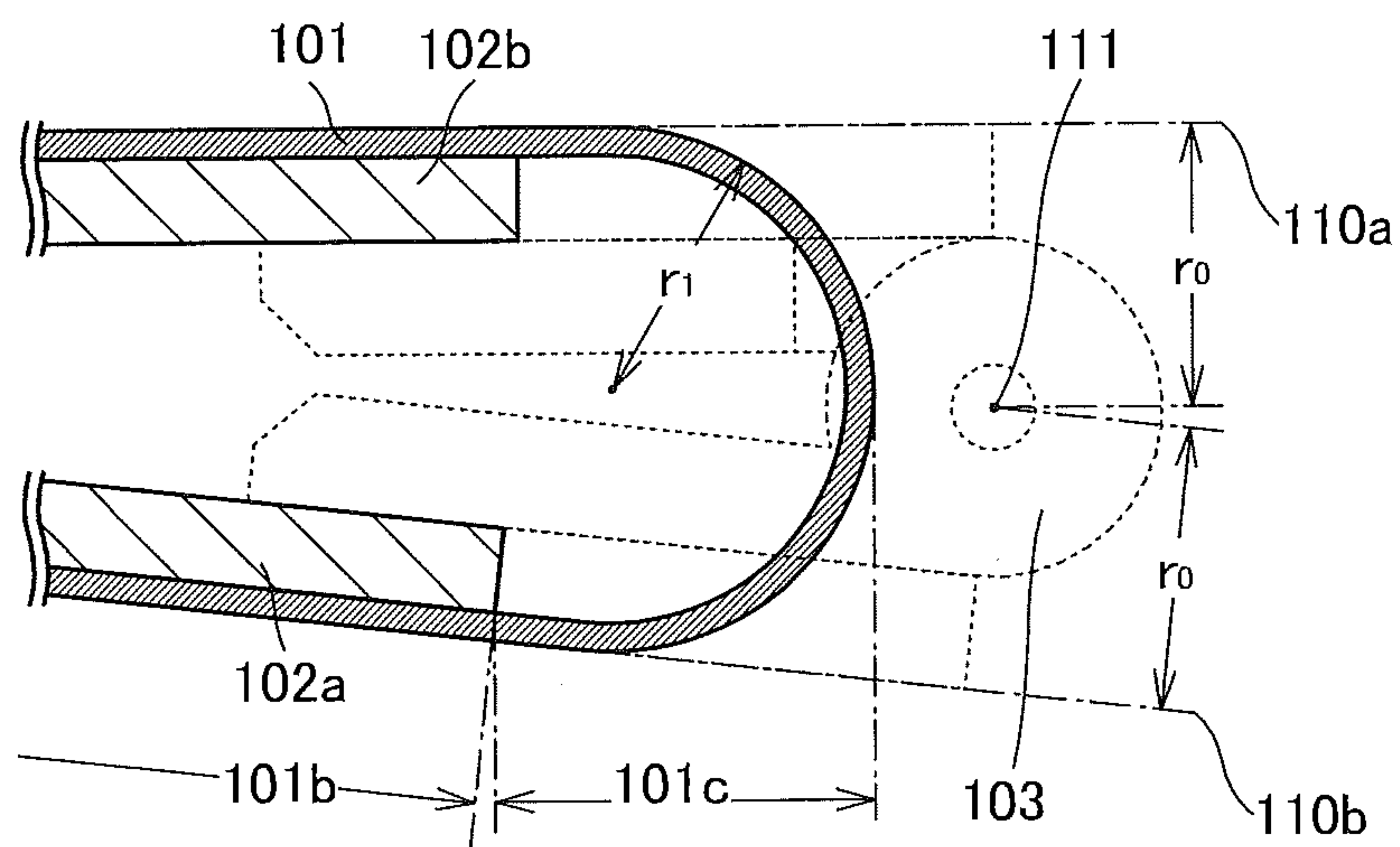


FIG. 8A

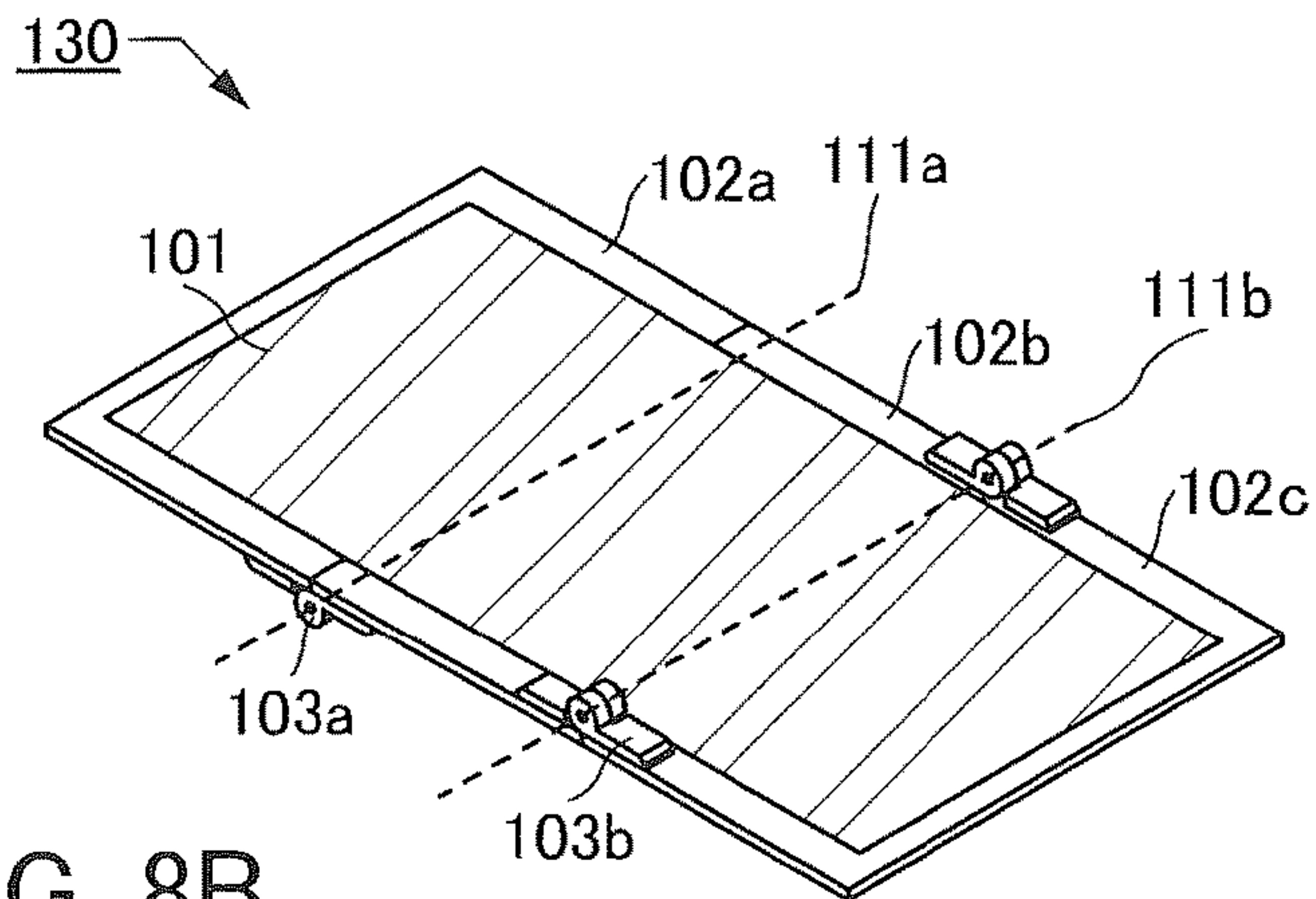


FIG. 8B

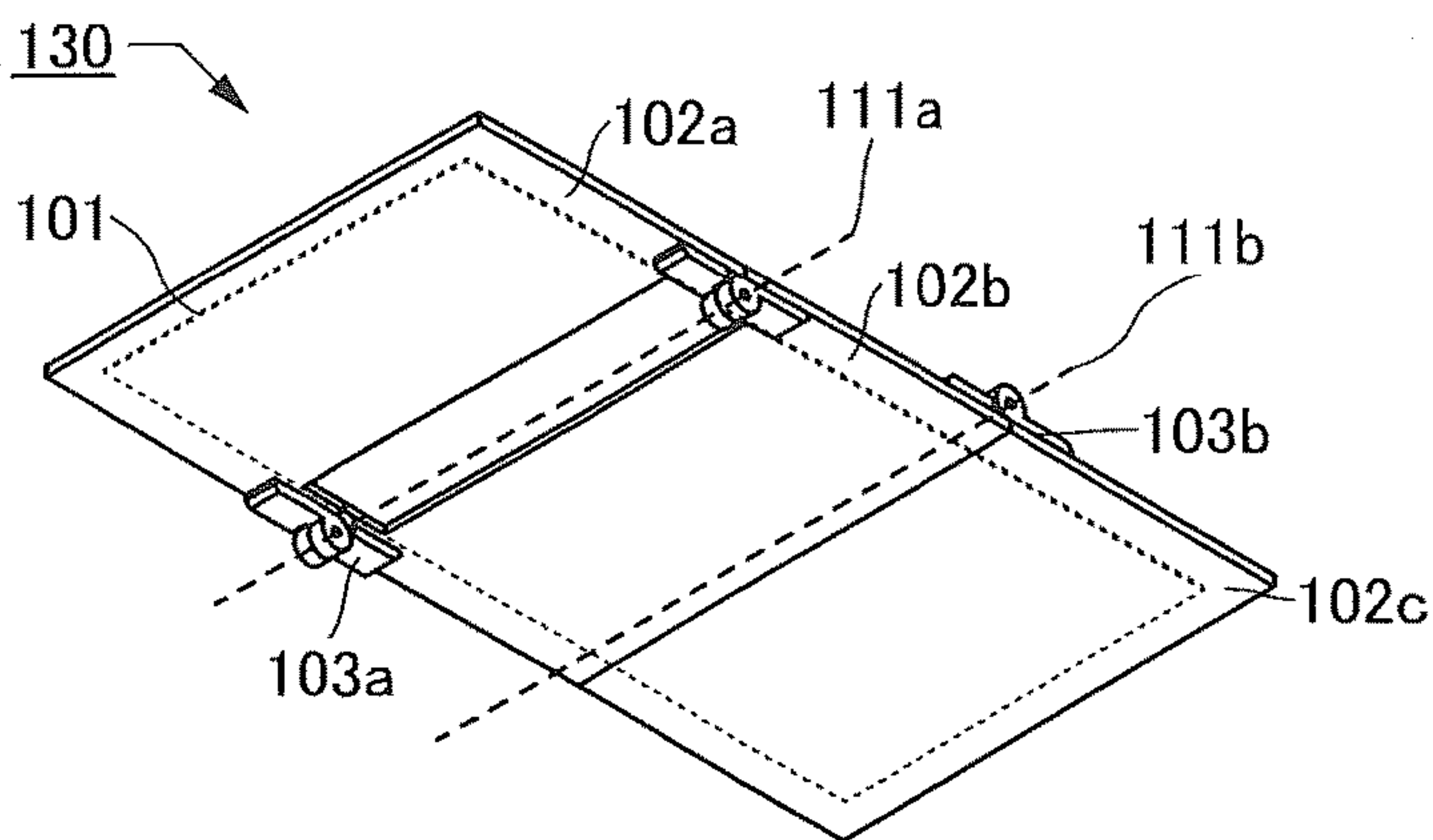


FIG. 8C

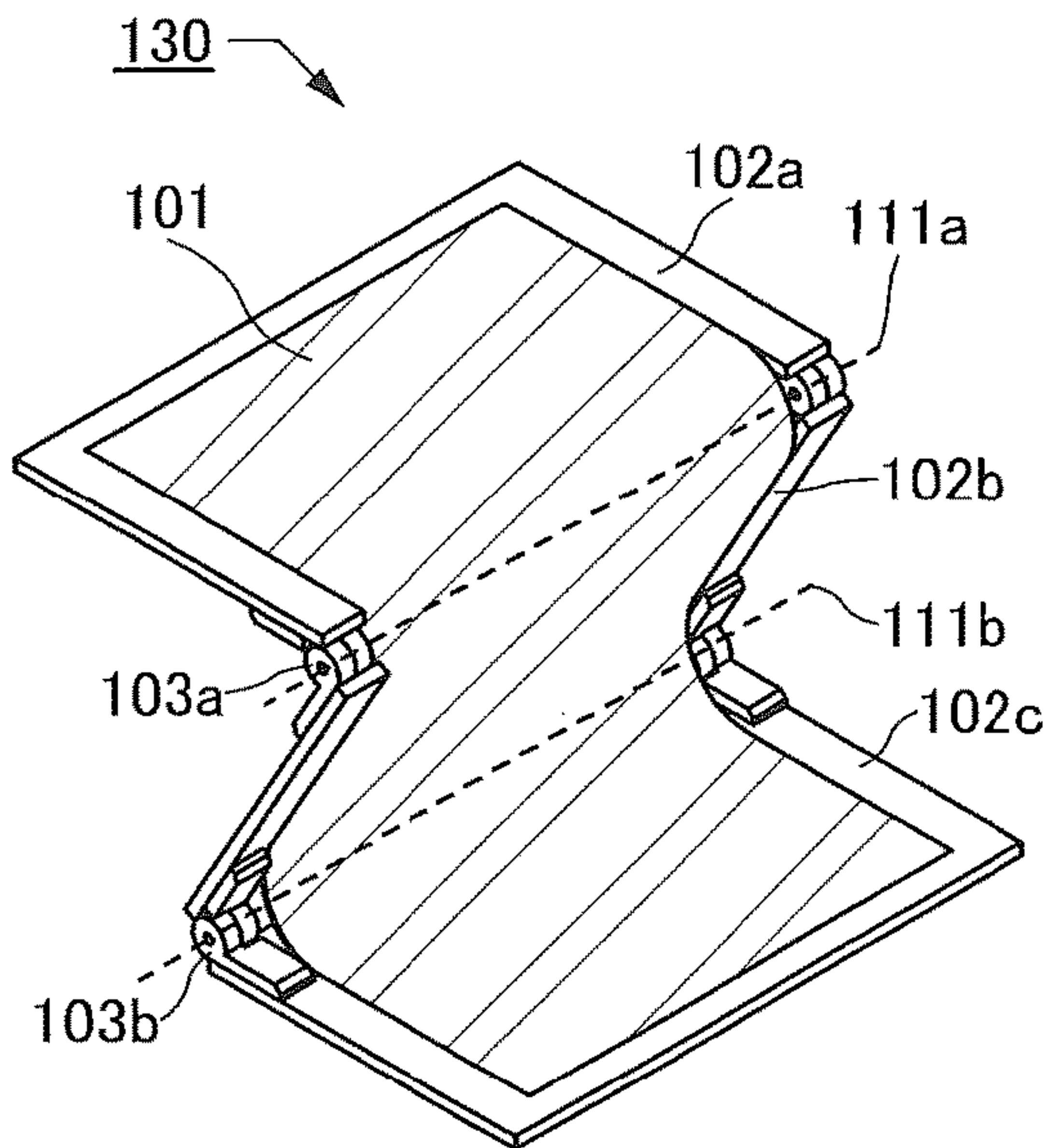


FIG. 8D

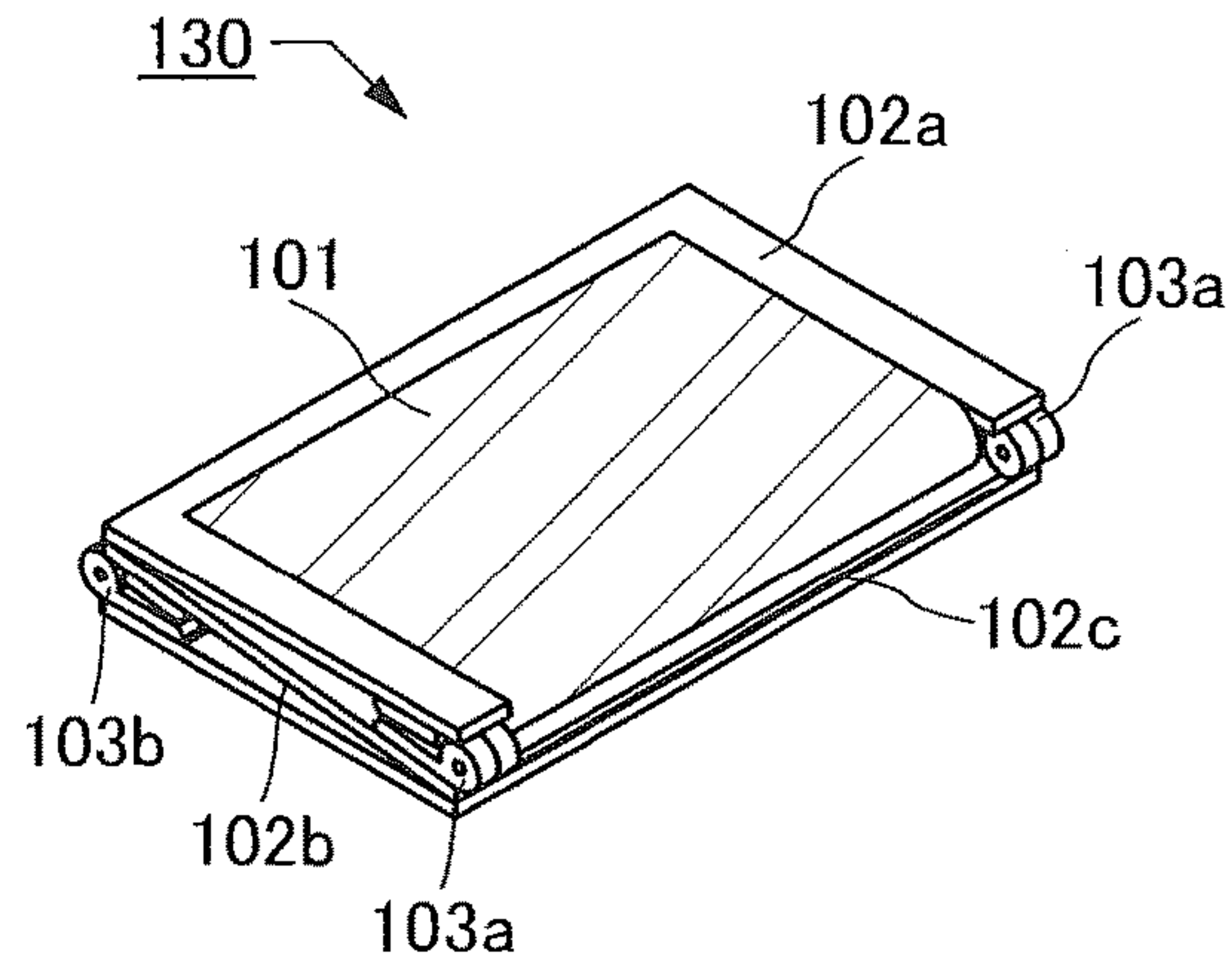








FIG. 10A

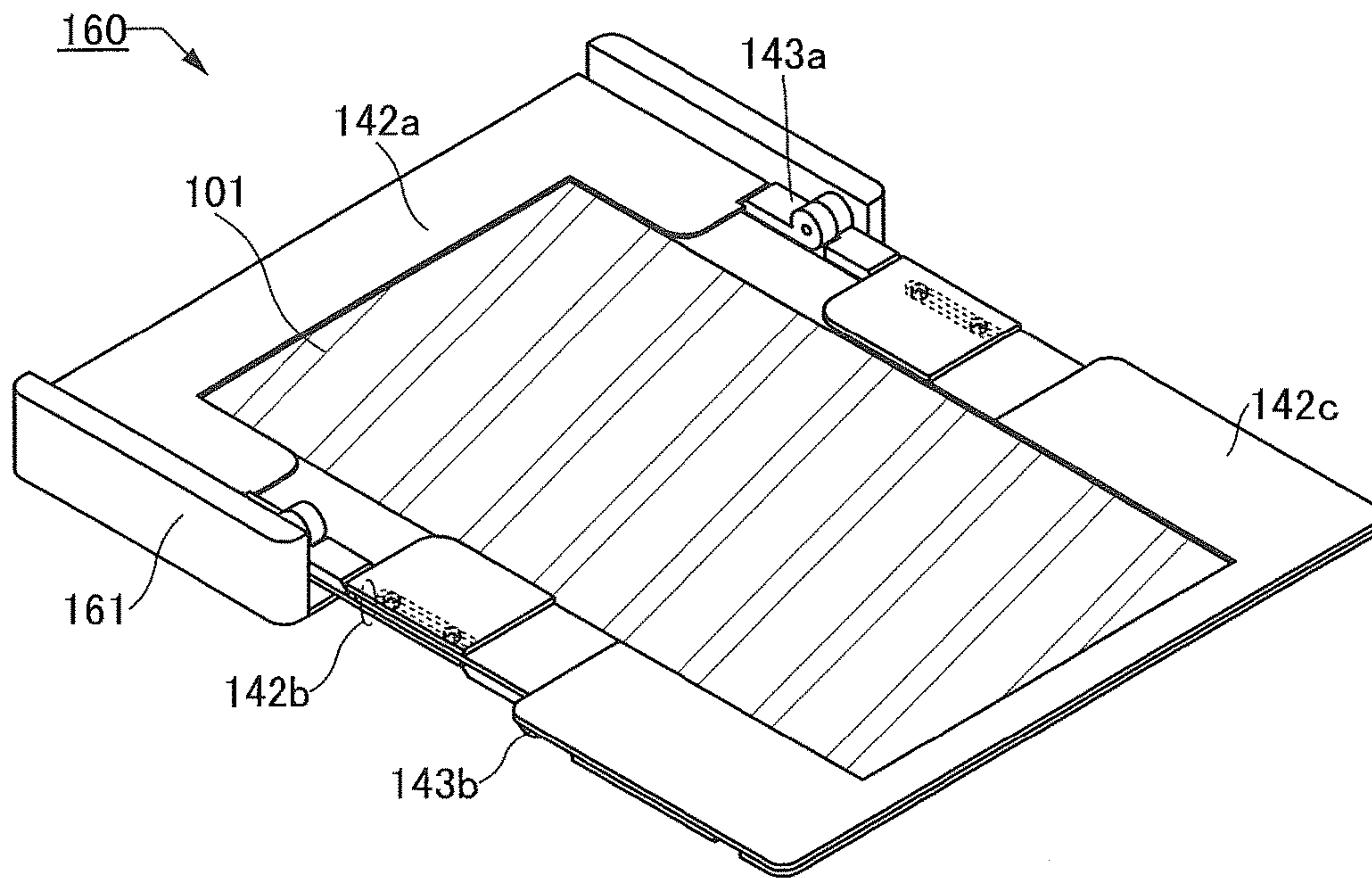


FIG. 10B

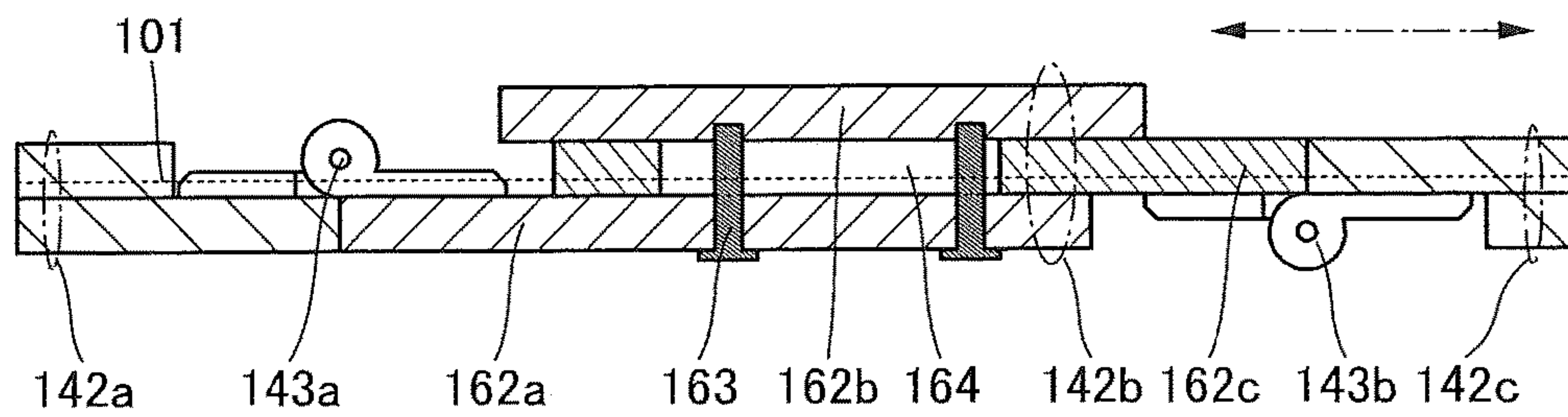


FIG. 11A

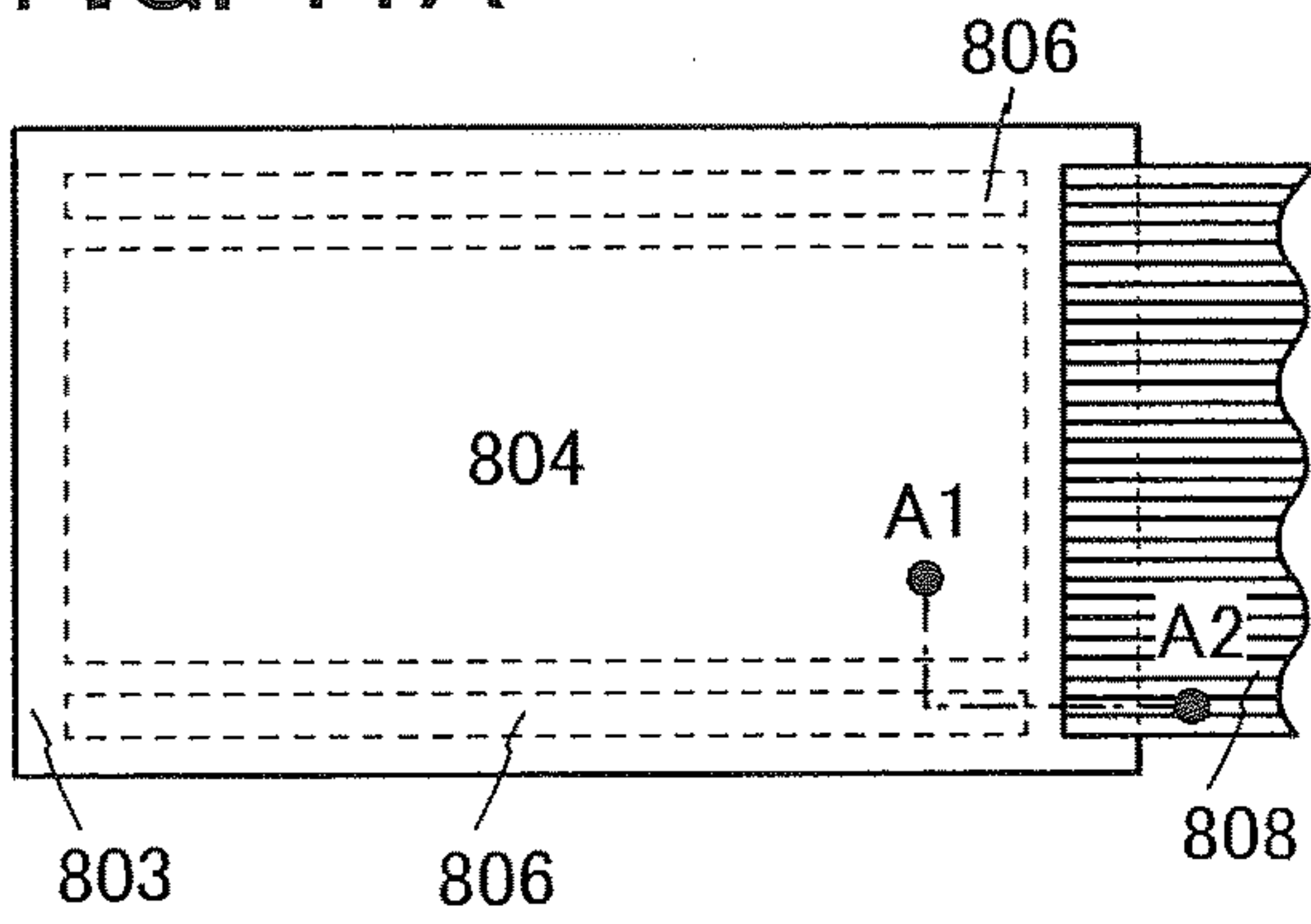


FIG. 11B

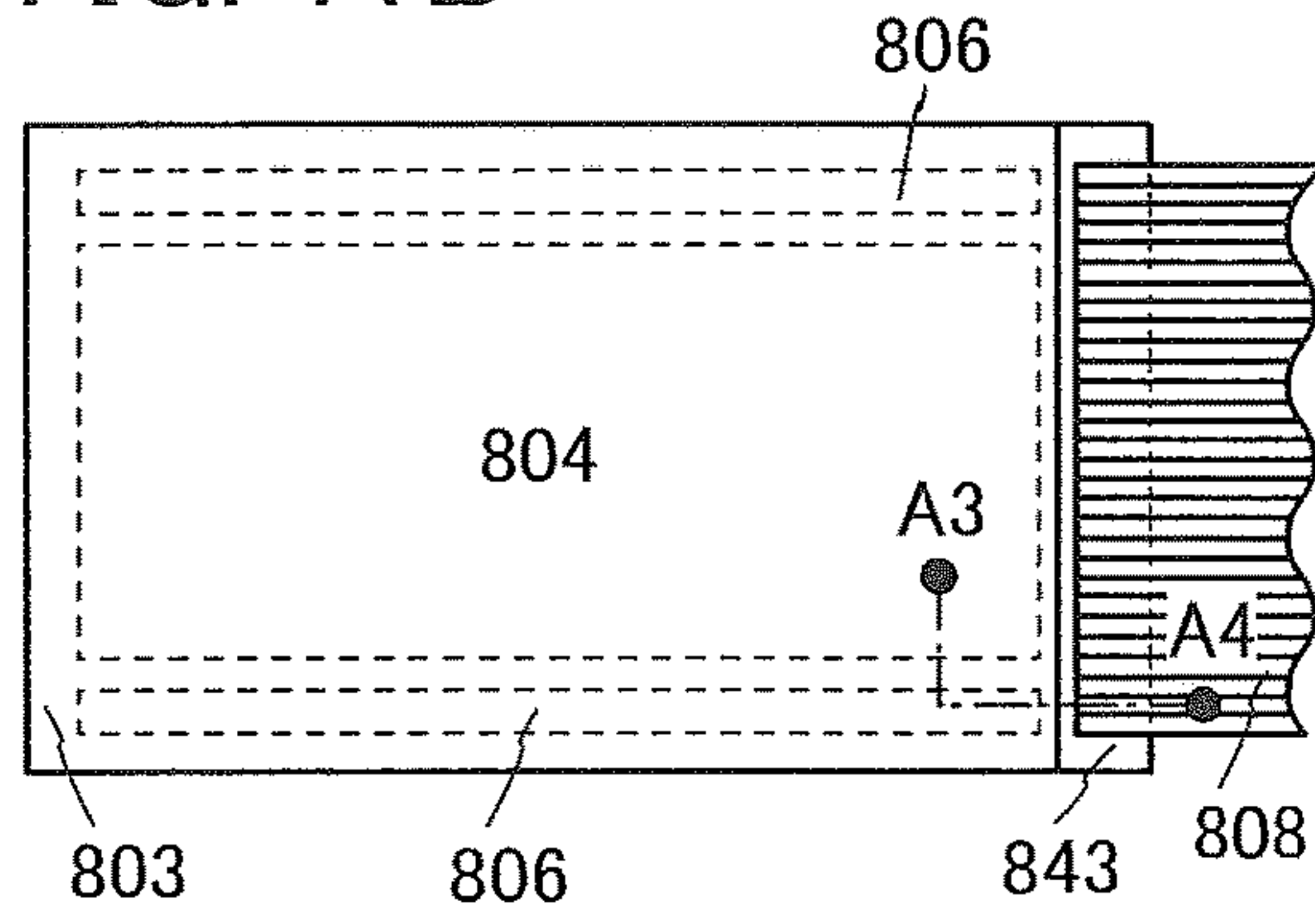


FIG. 11C

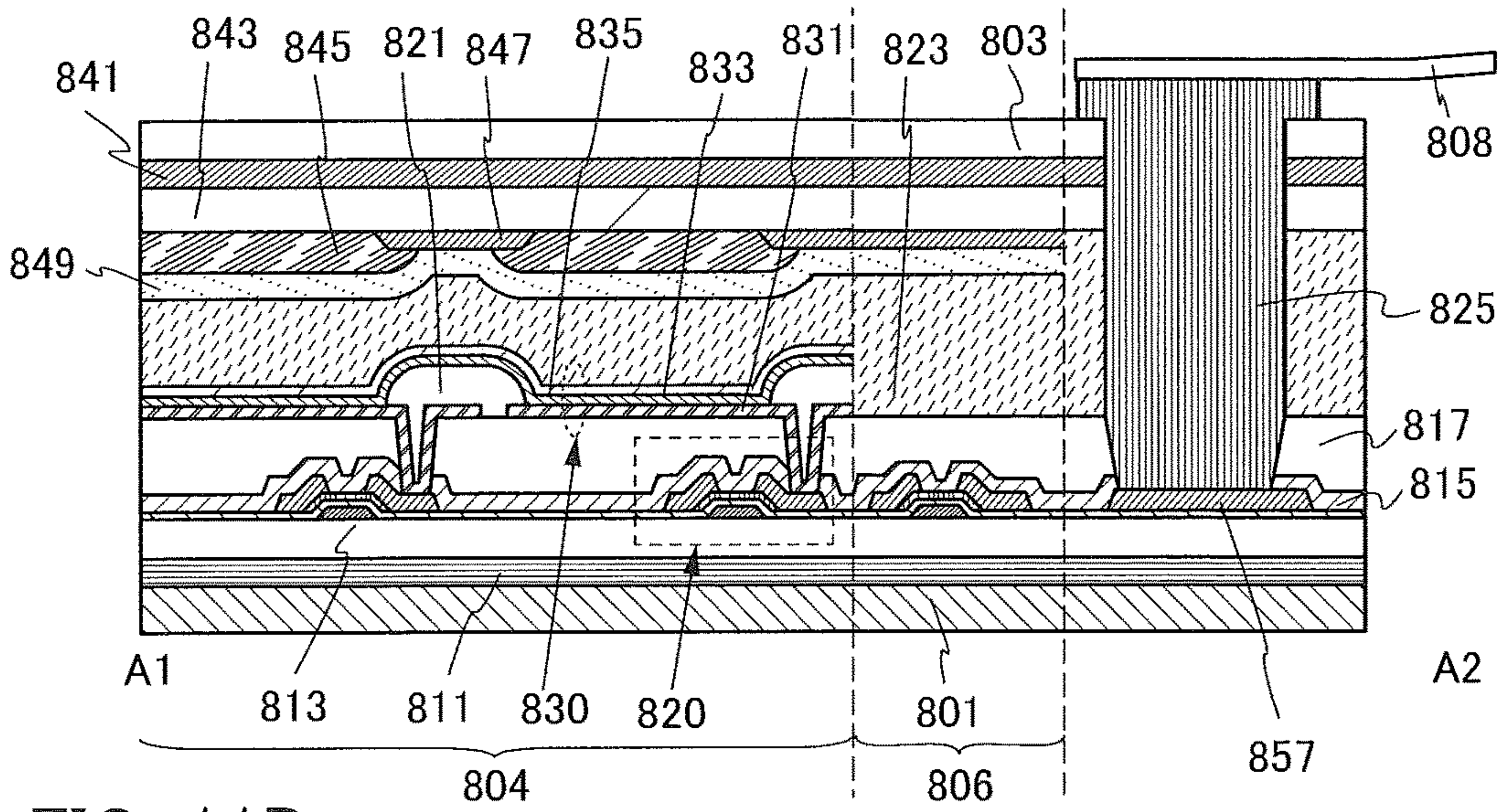


FIG. 11D

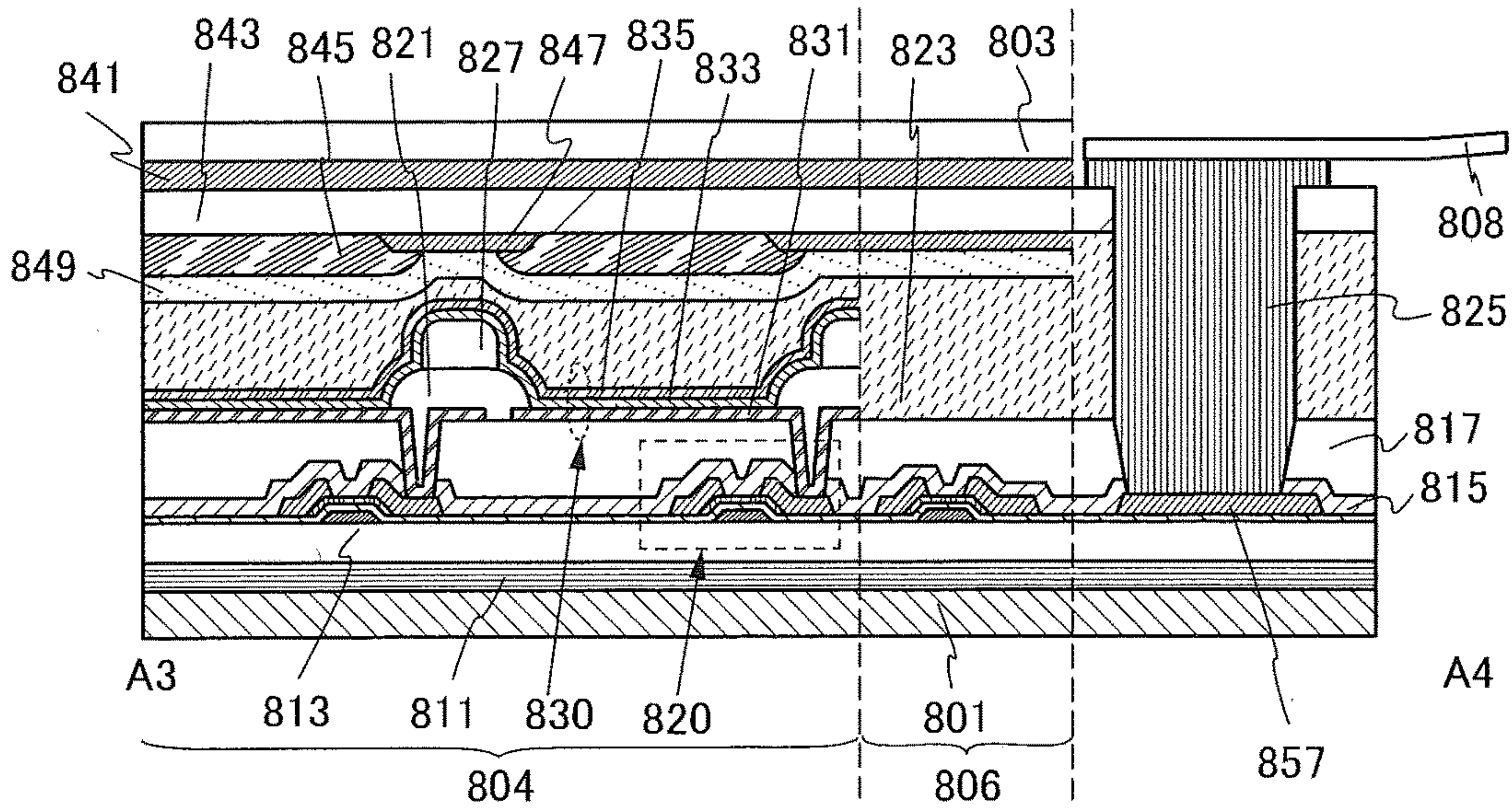




FIG. 12A

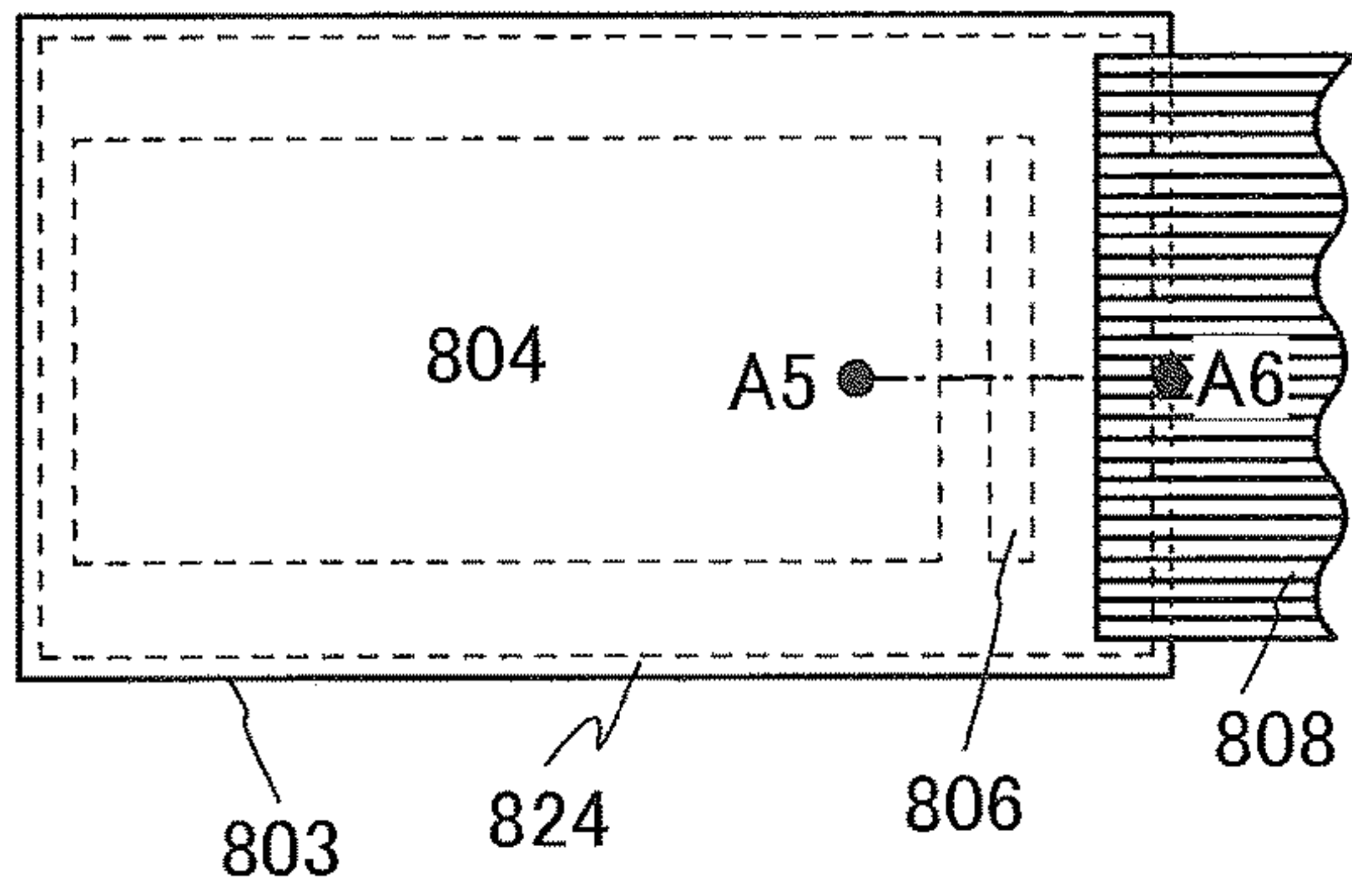


FIG. 12B

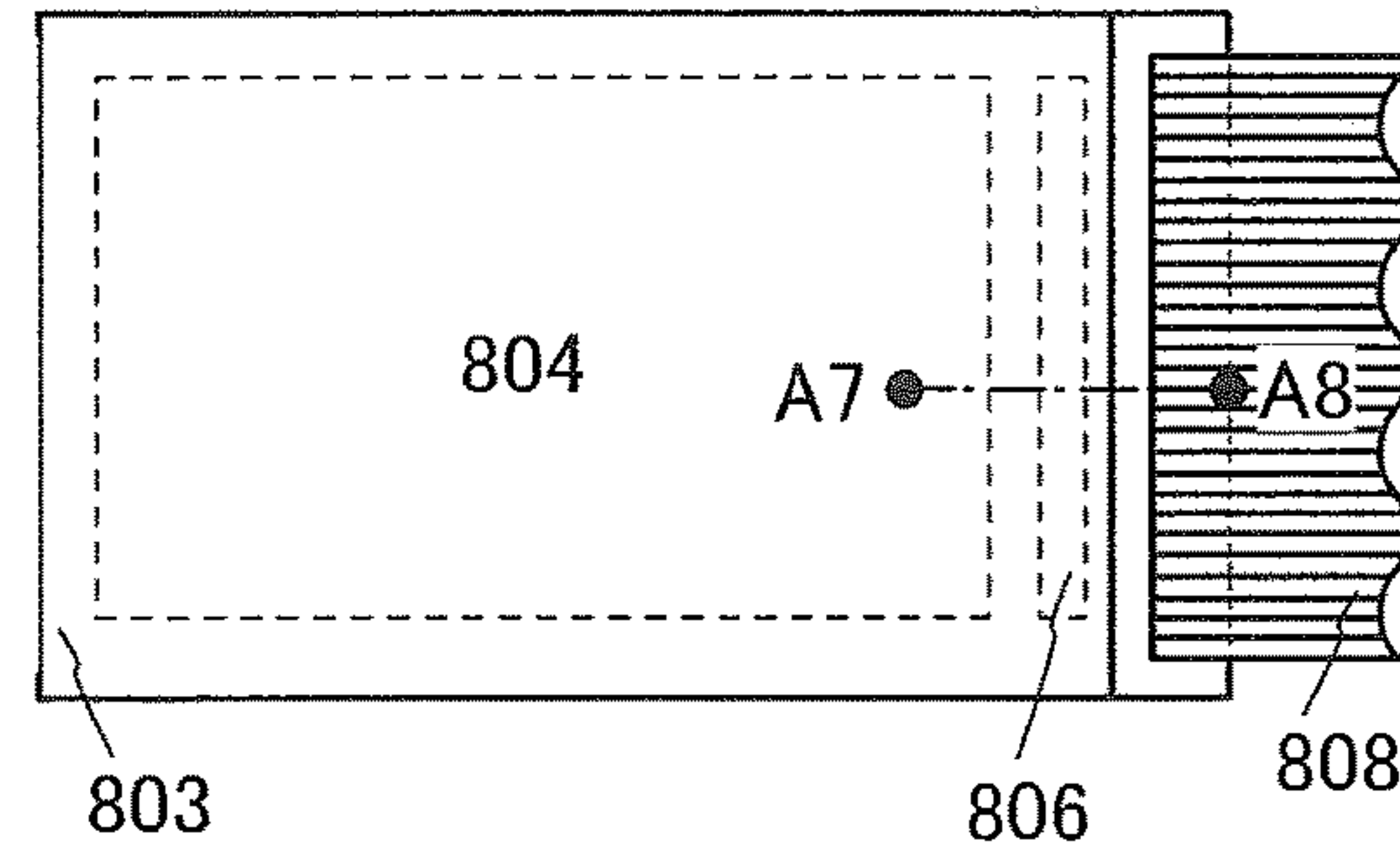


FIG. 12C

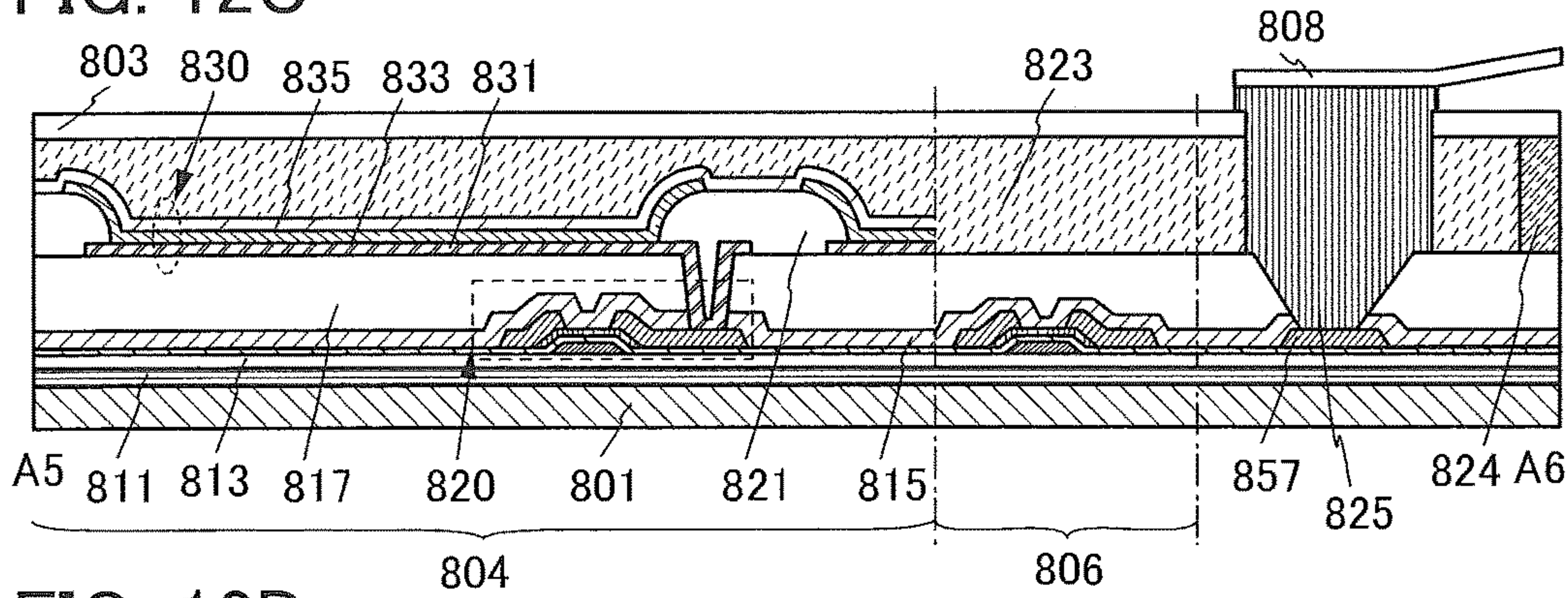


FIG. 12D

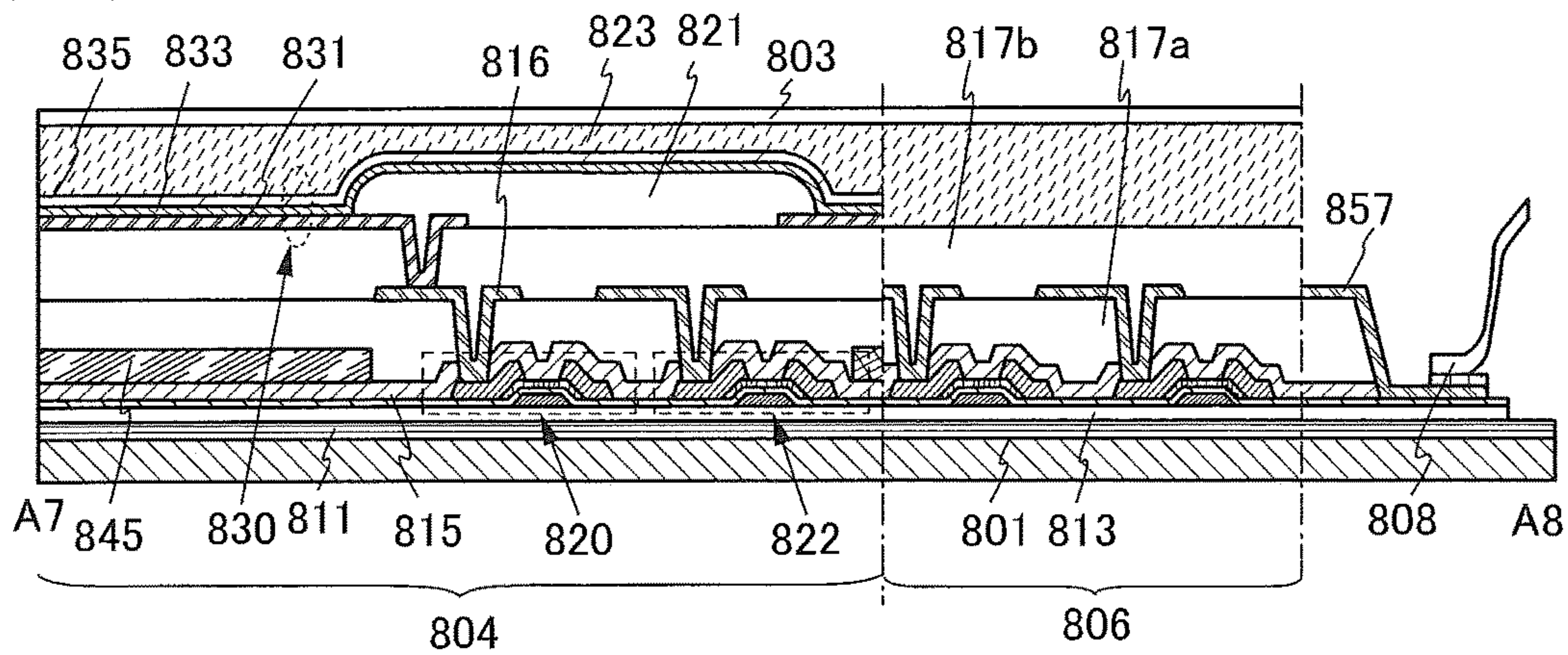


FIG. 12E

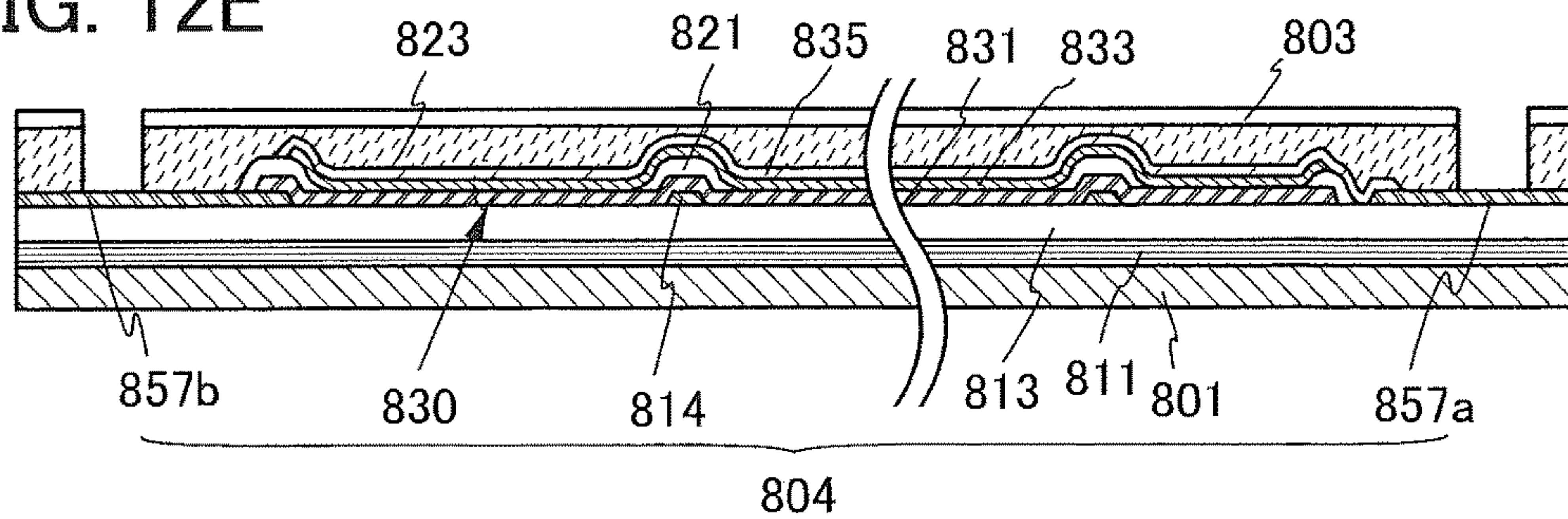




FIG. 13A

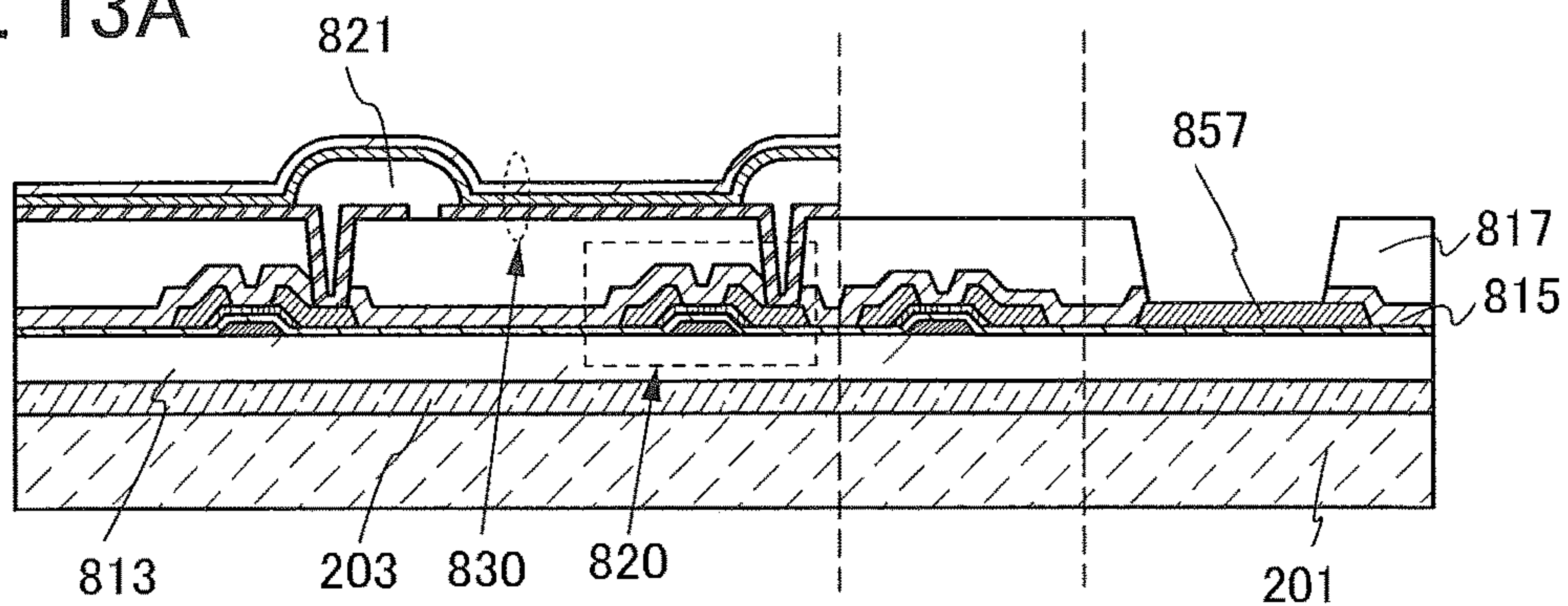


FIG. 13B

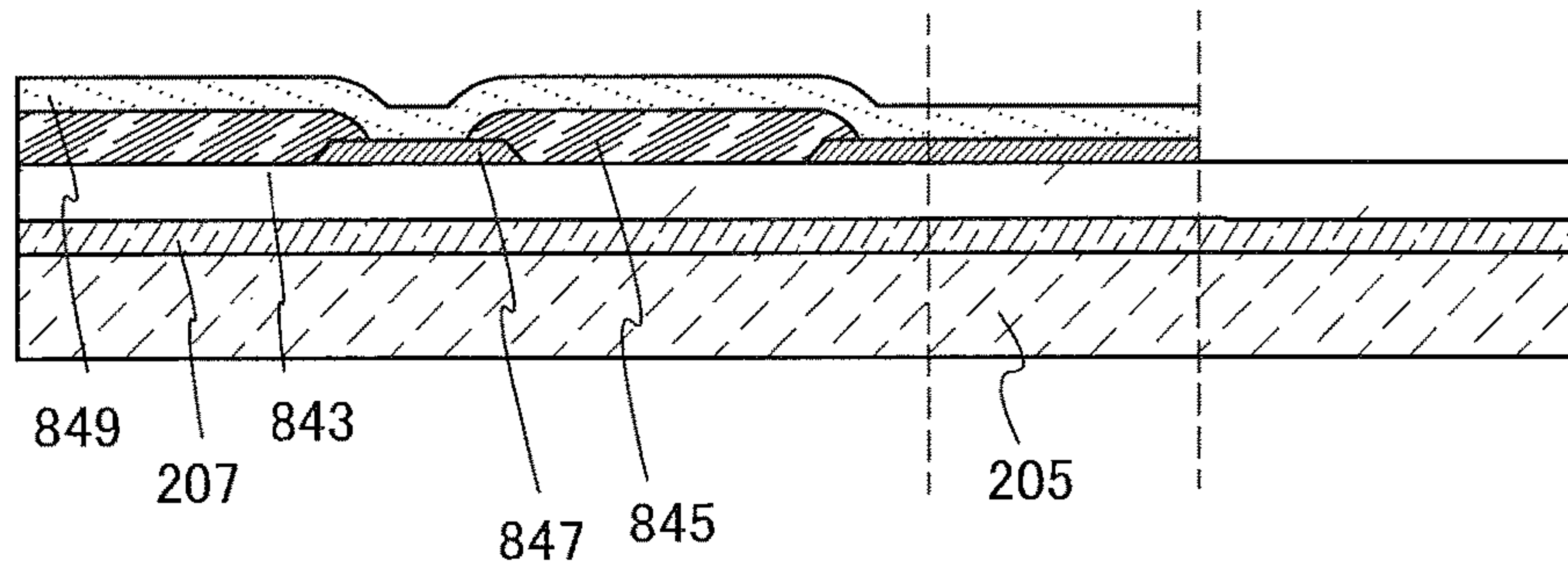


FIG. 13C

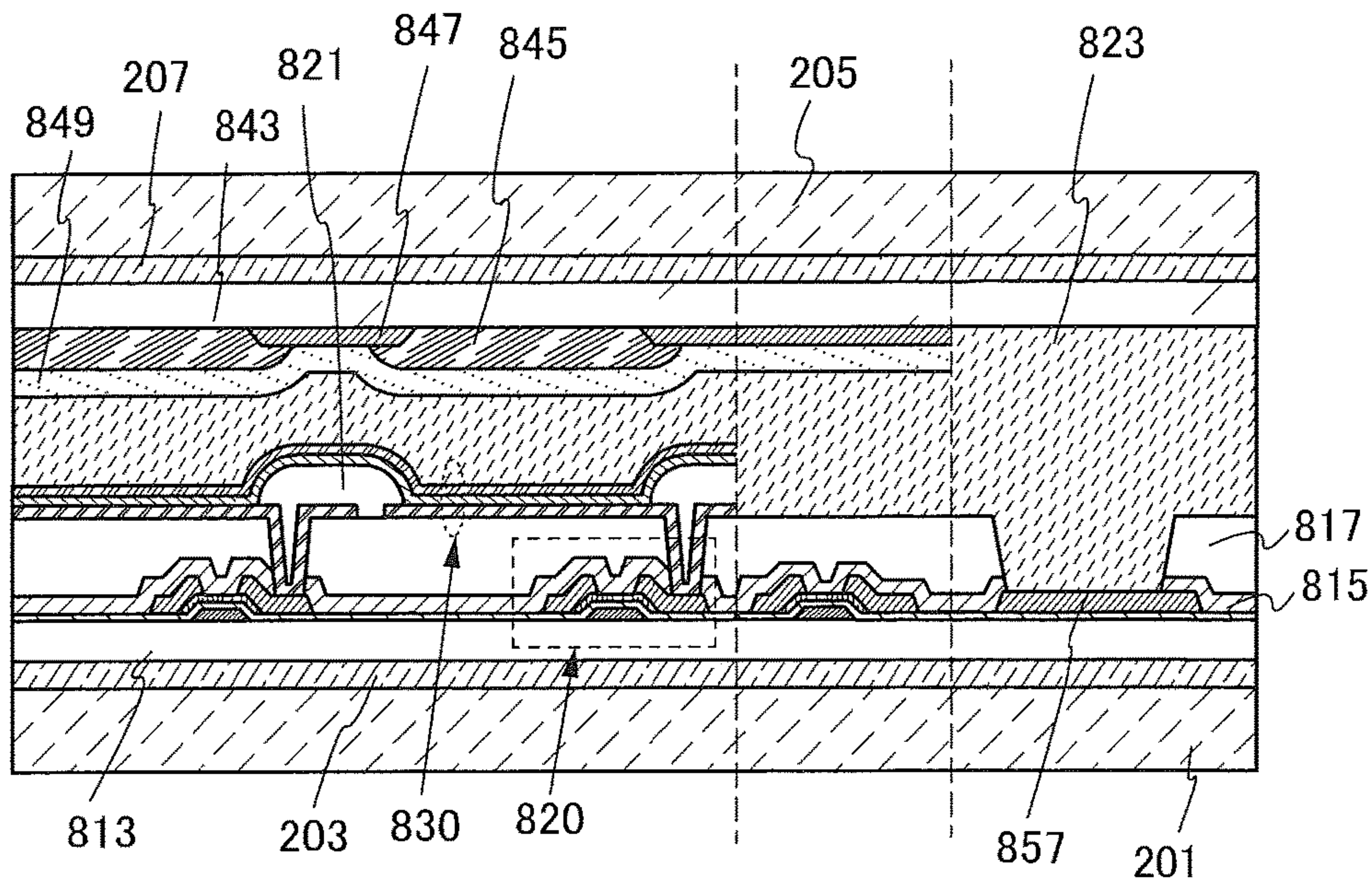




FIG. 14A

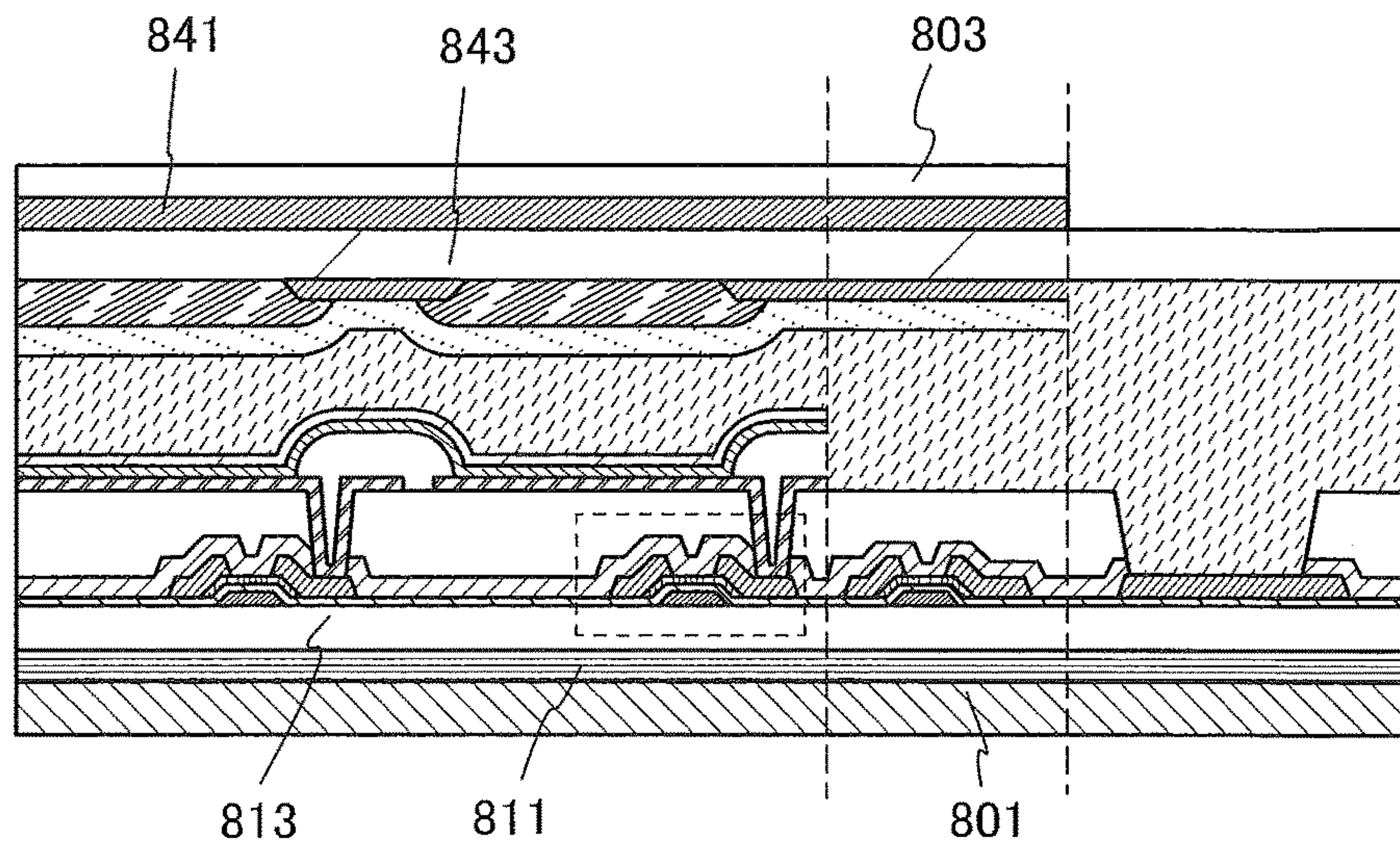


FIG. 14B

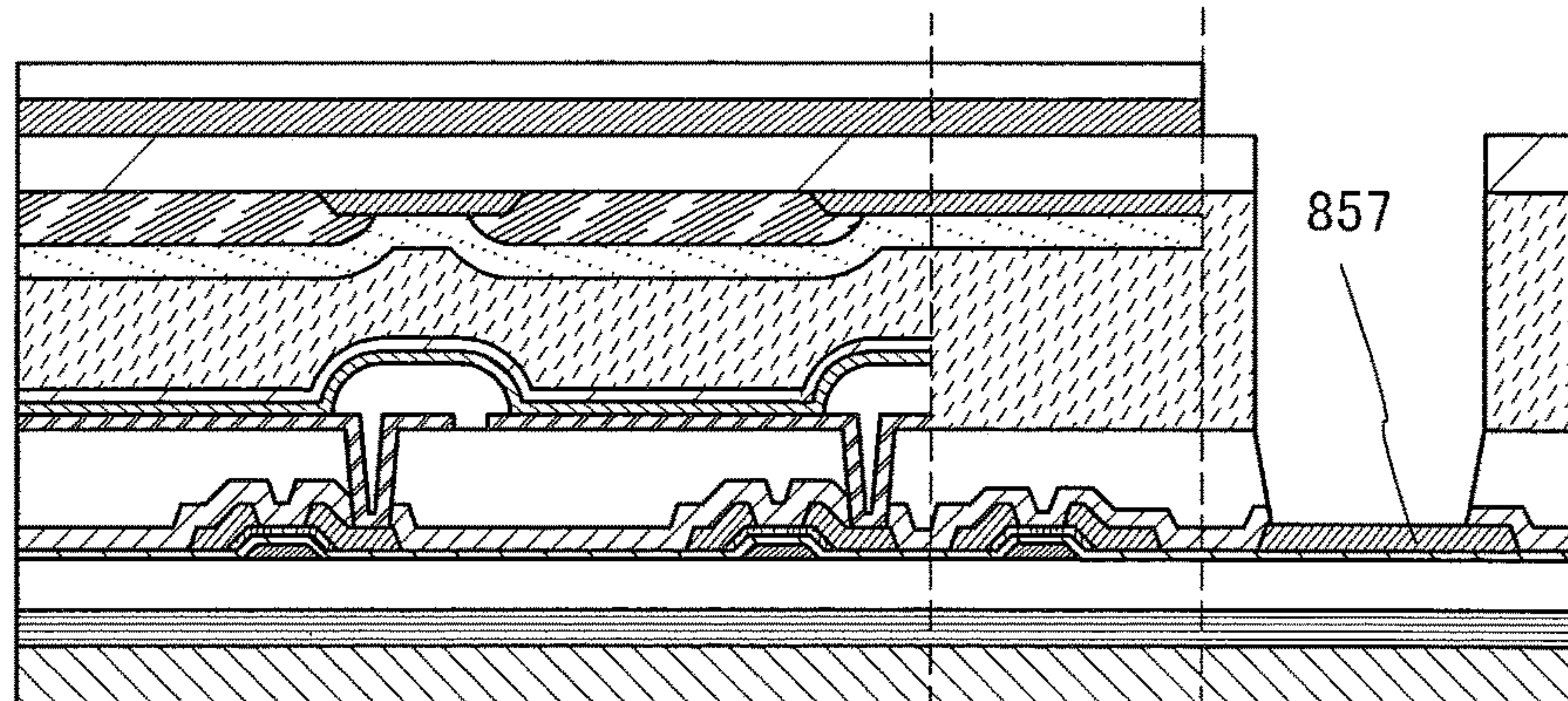


FIG. 14C

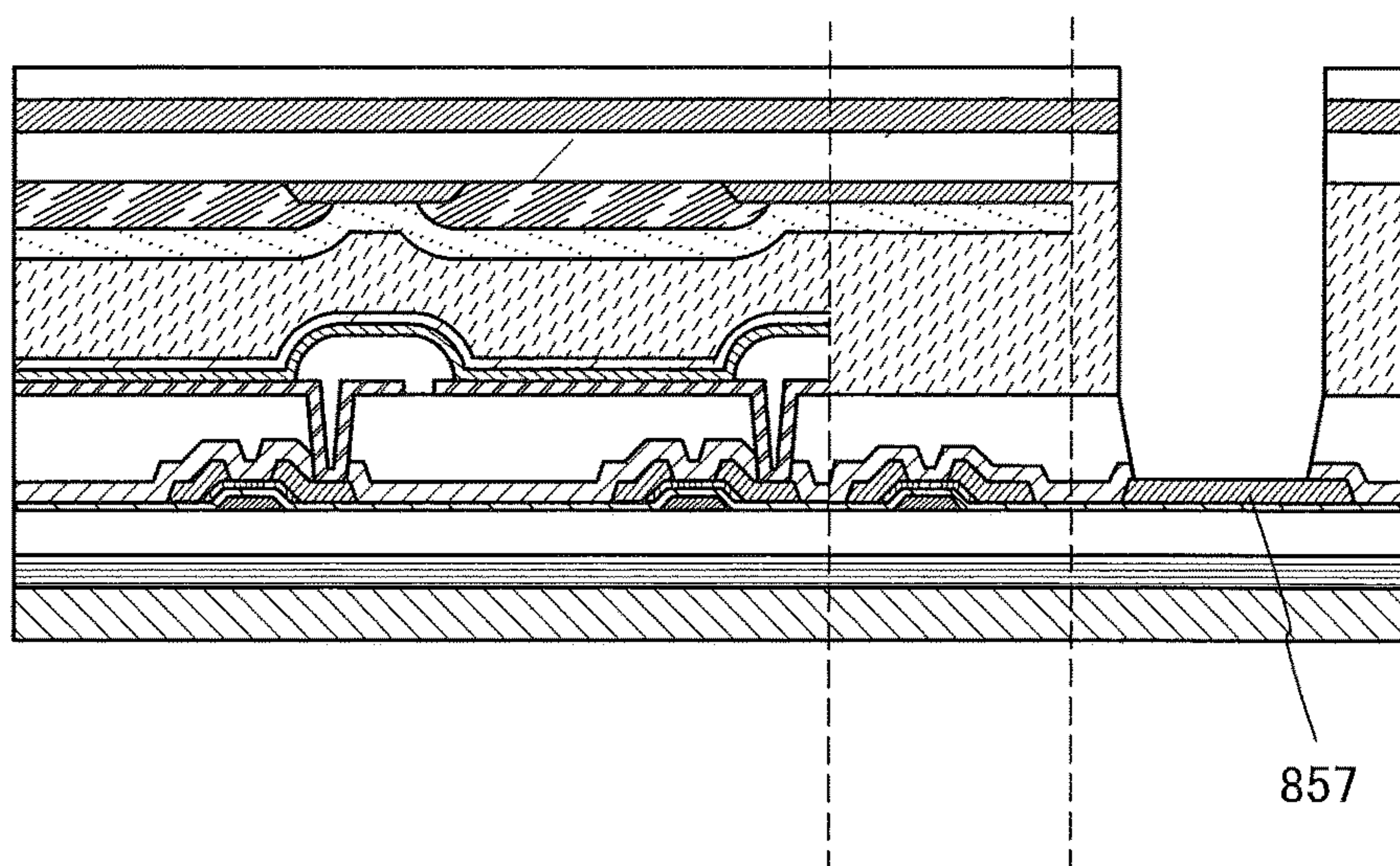




FIG. 15A

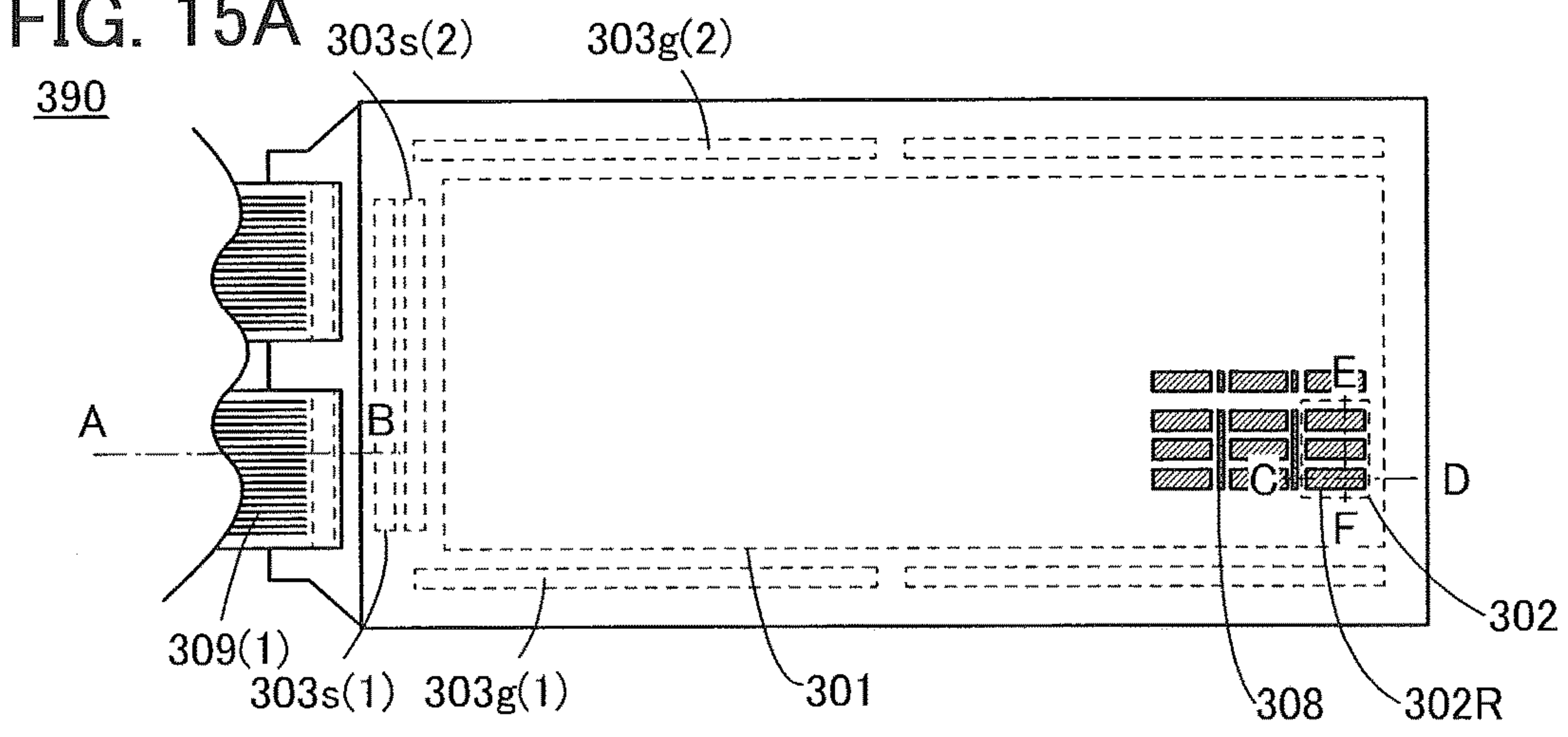


FIG. 15B

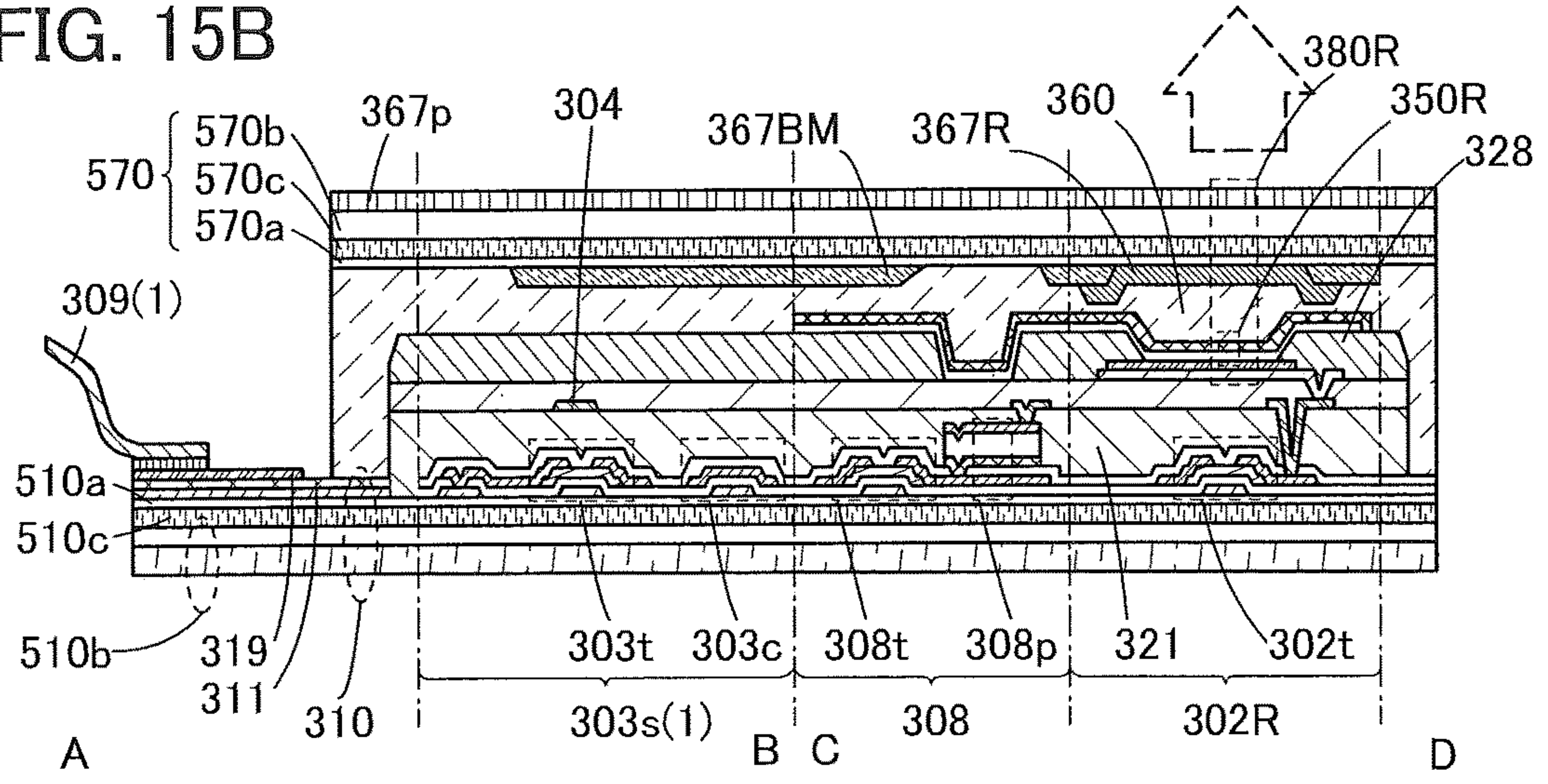


FIG. 15C

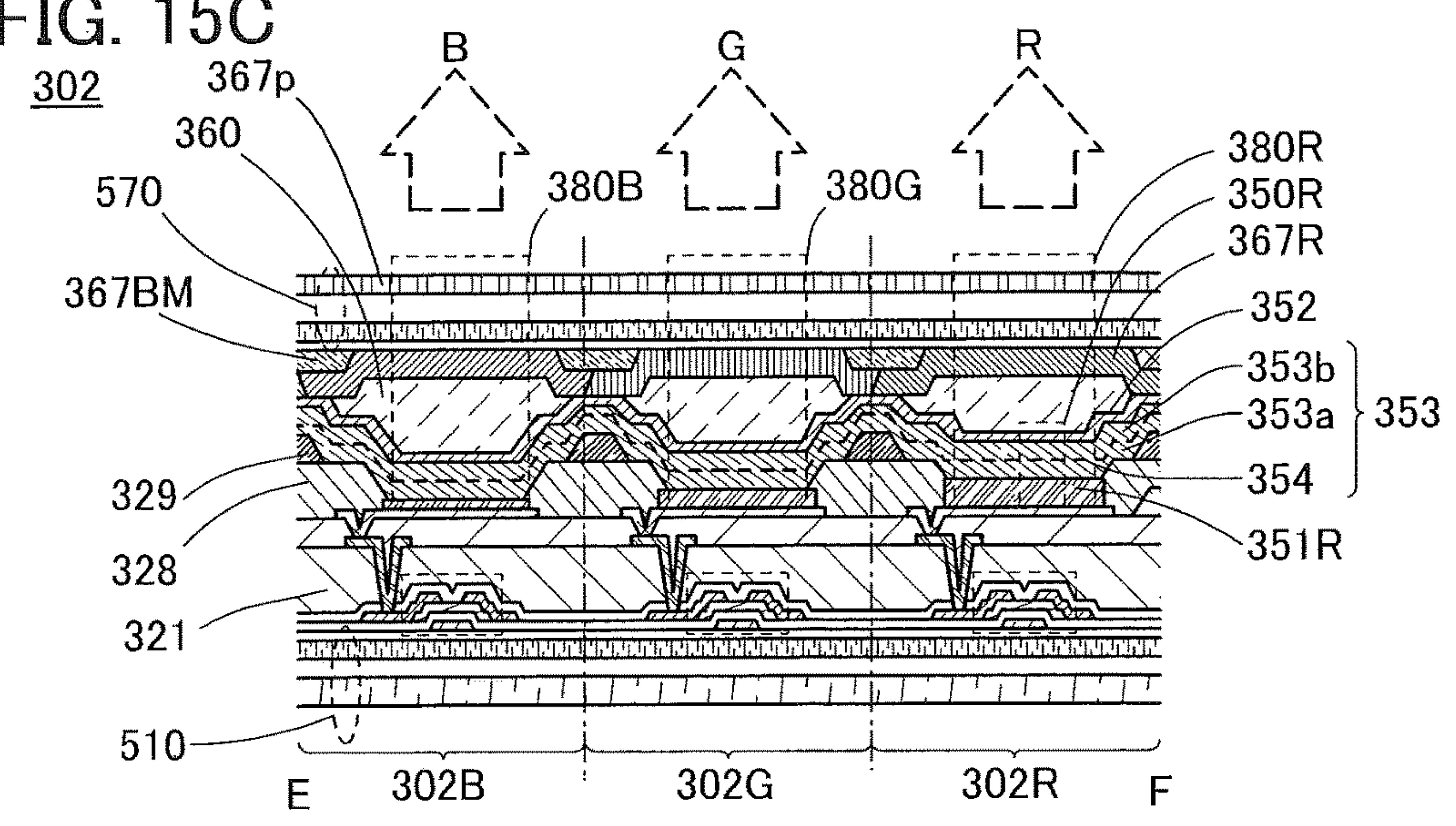




FIG. 16A

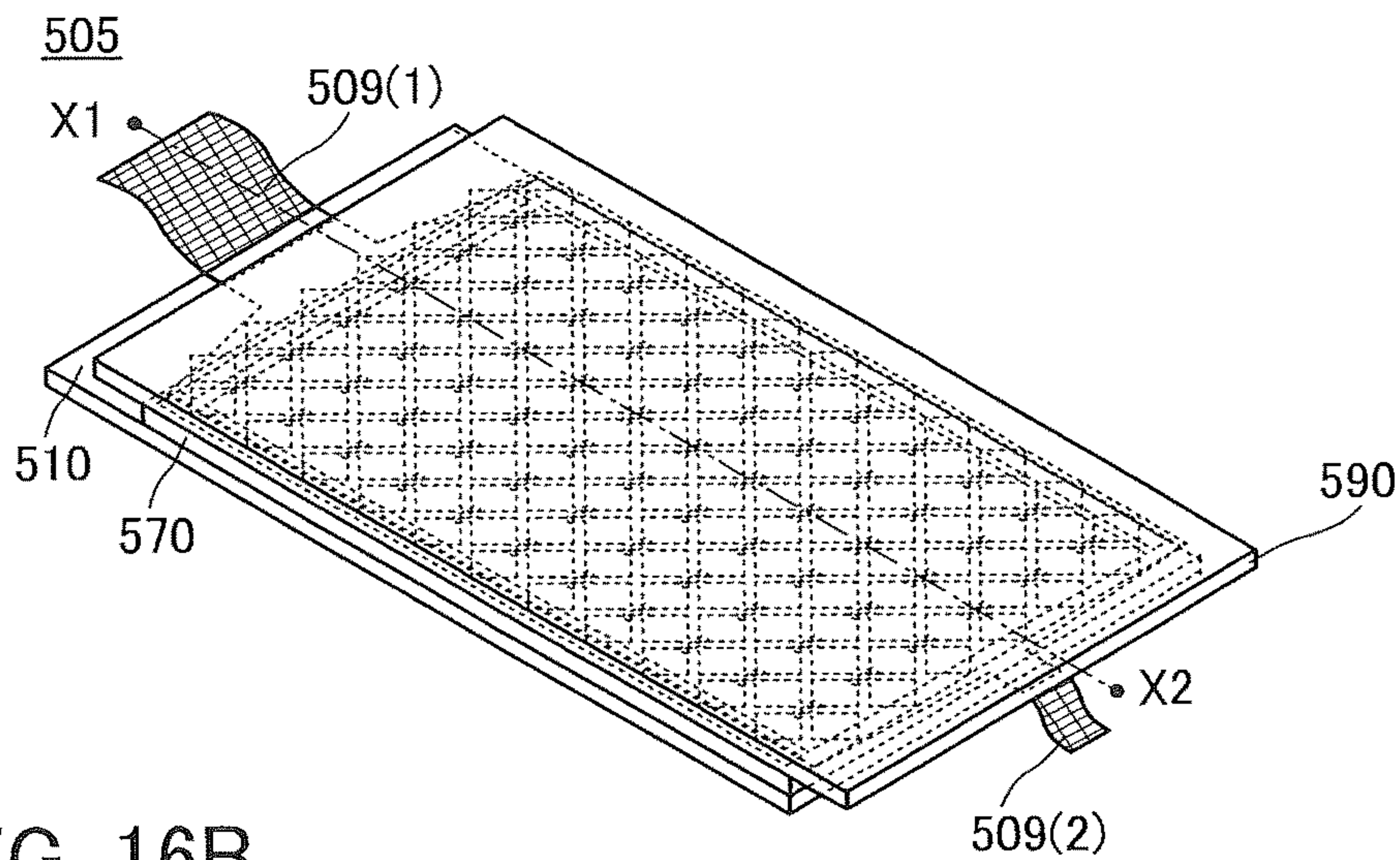


FIG. 16B

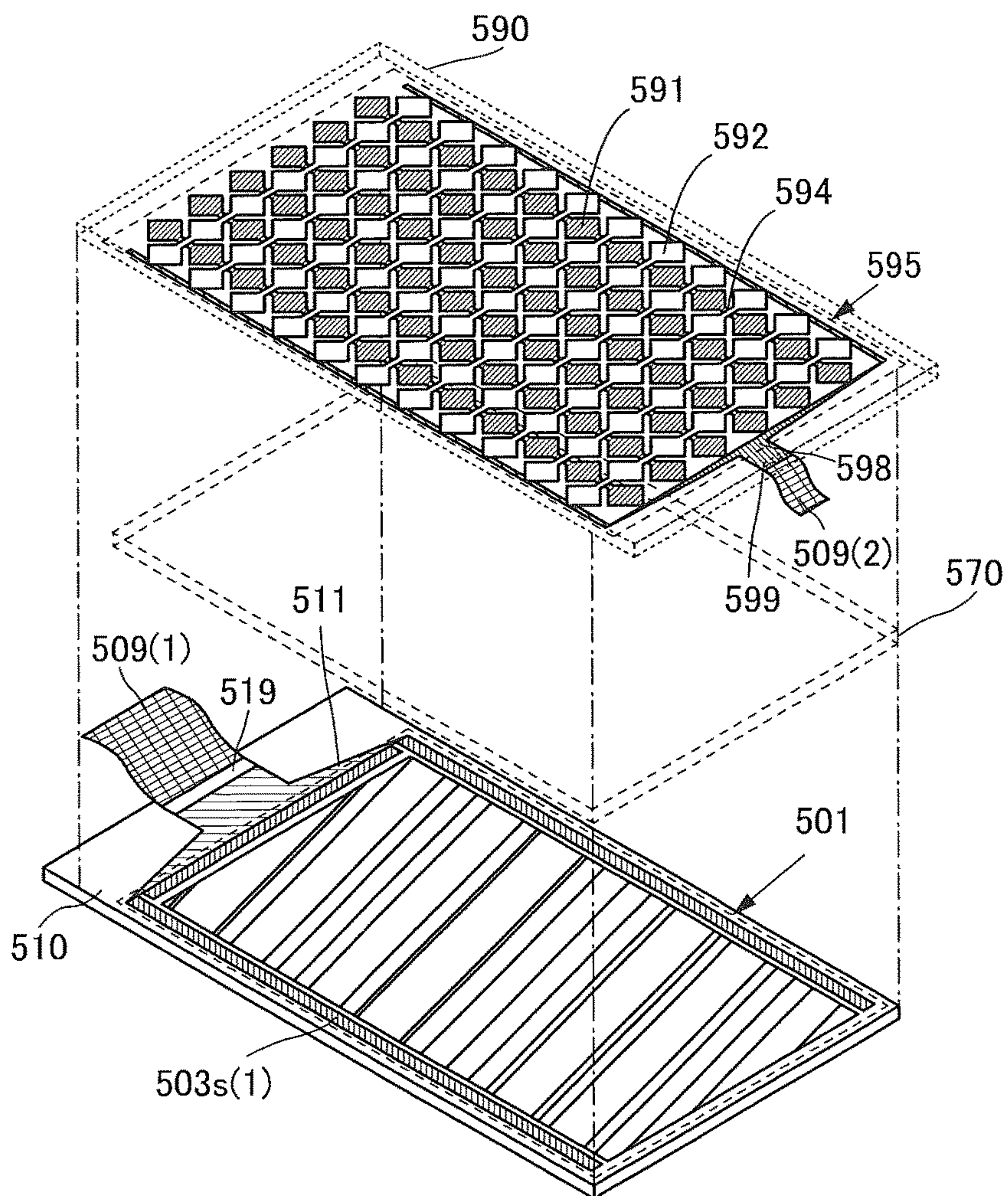


FIG. 17A

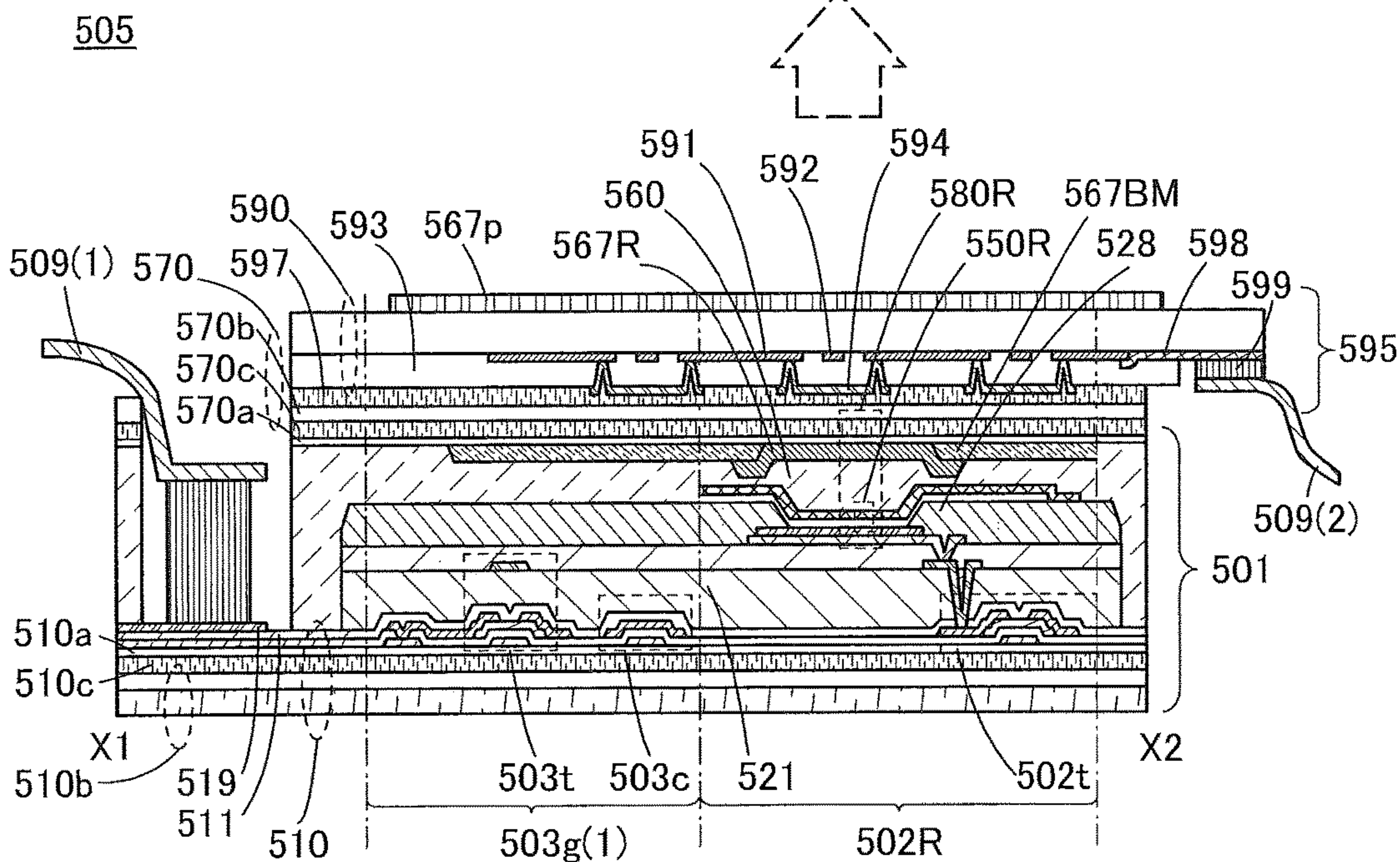


FIG. 17B

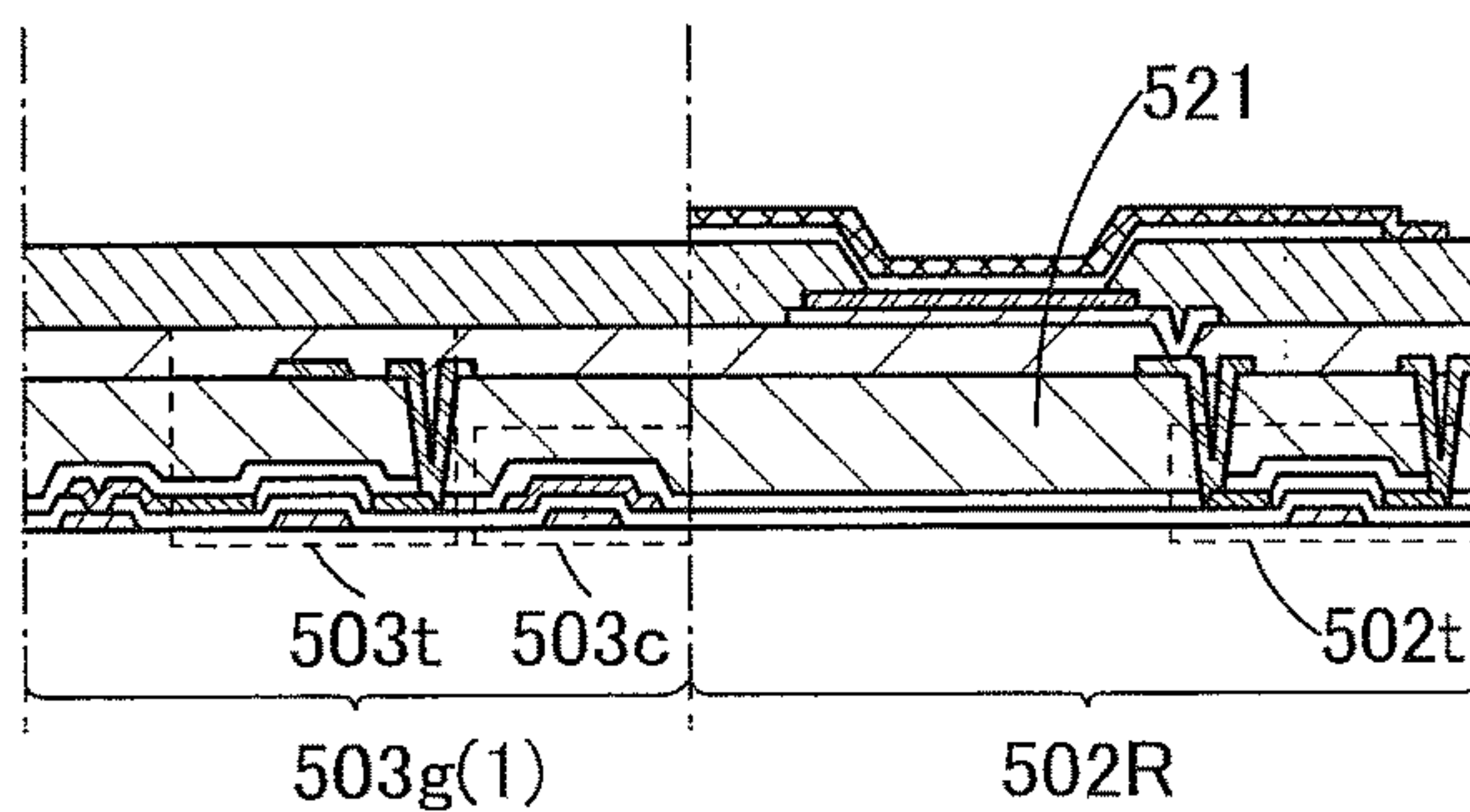


FIG. 17C

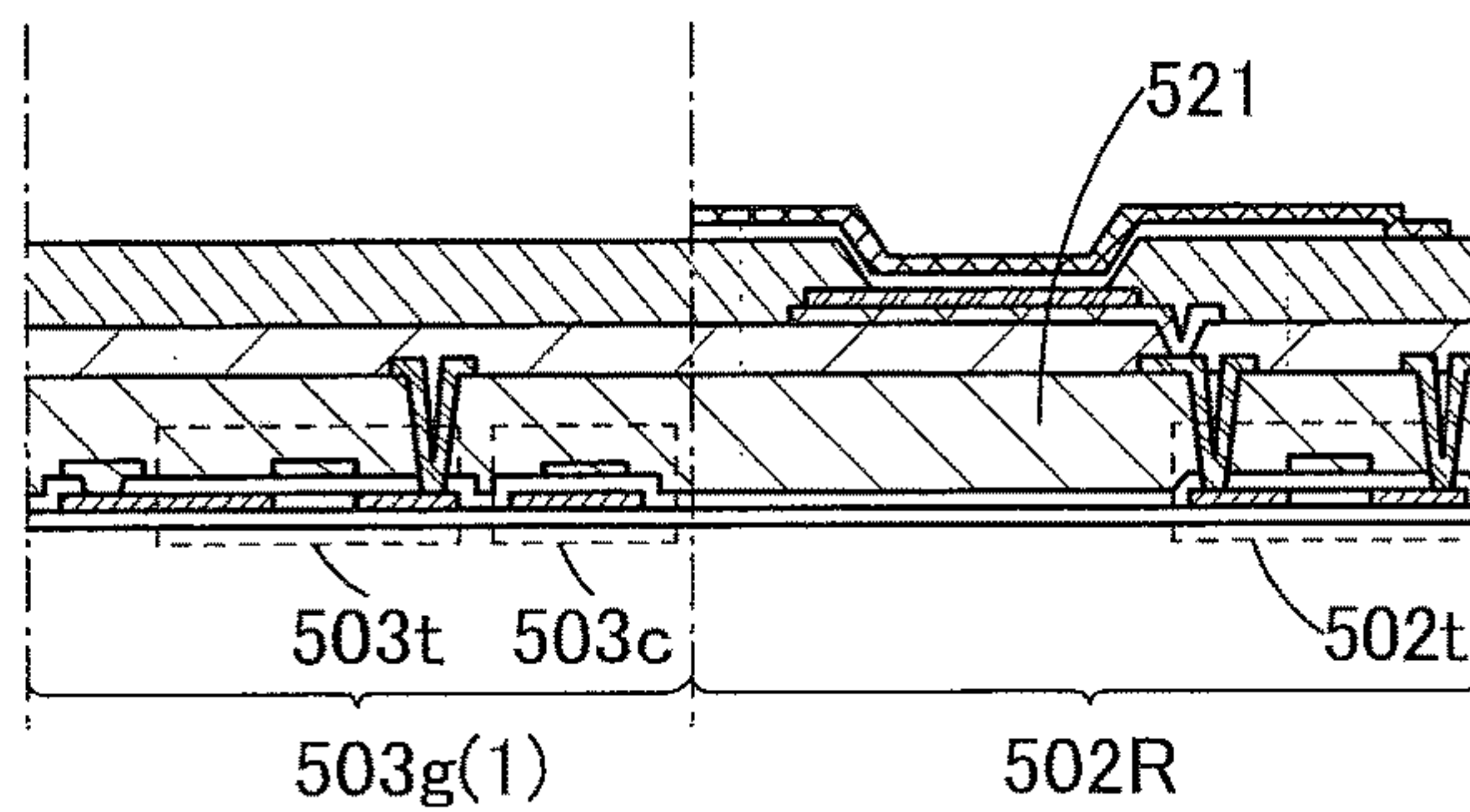




FIG. 18A

505B

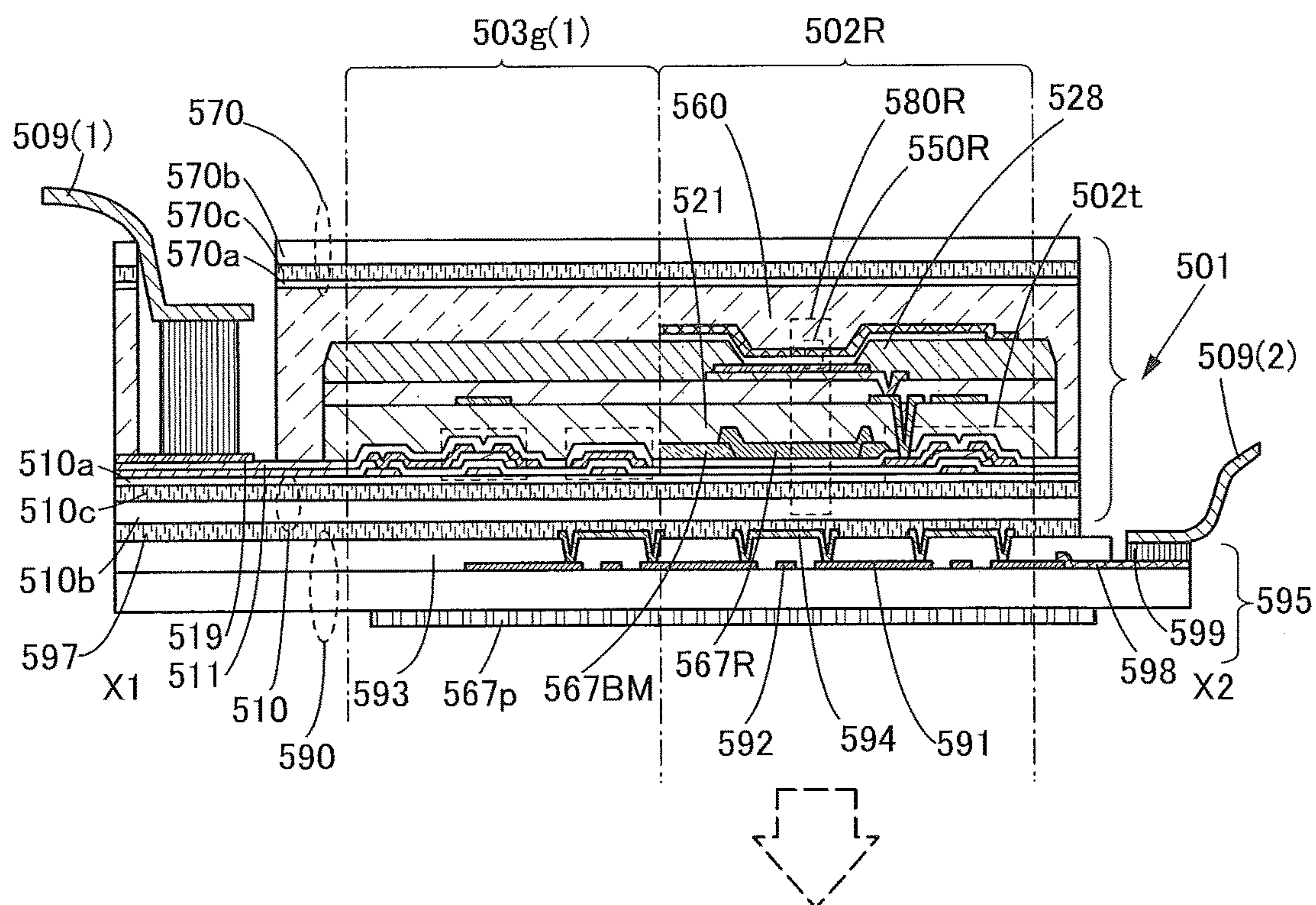


FIG. 18B

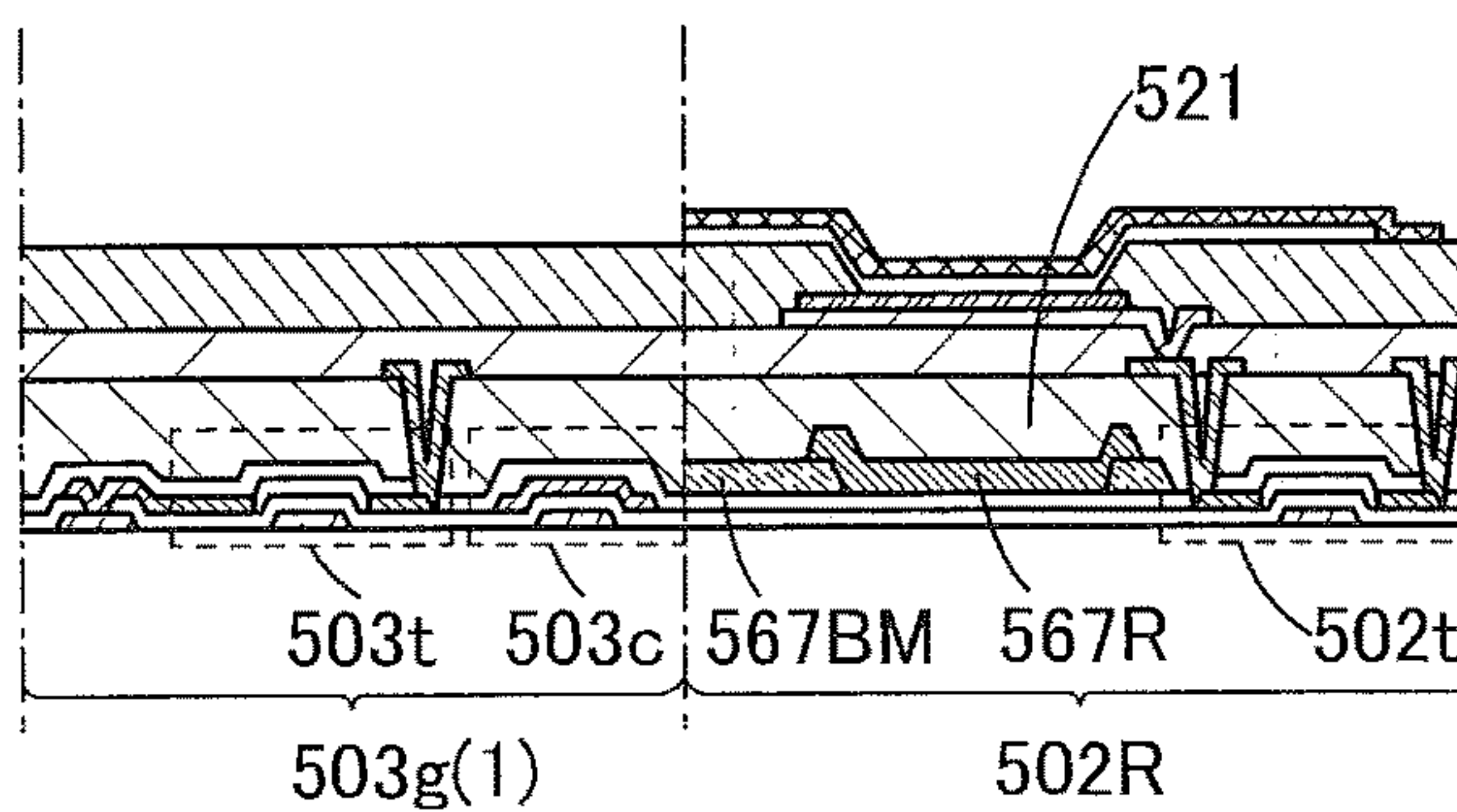


FIG. 18C

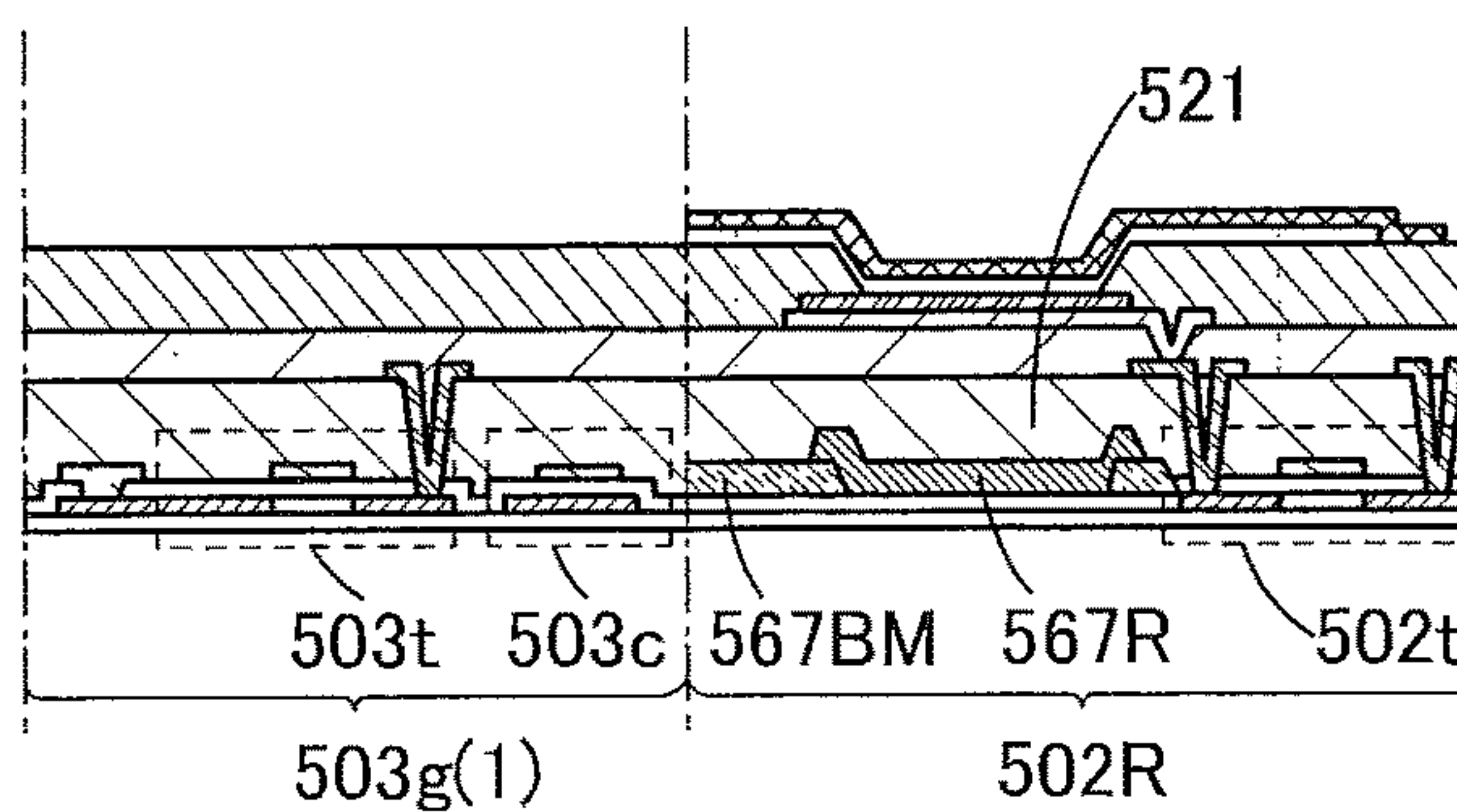




FIG. 19A

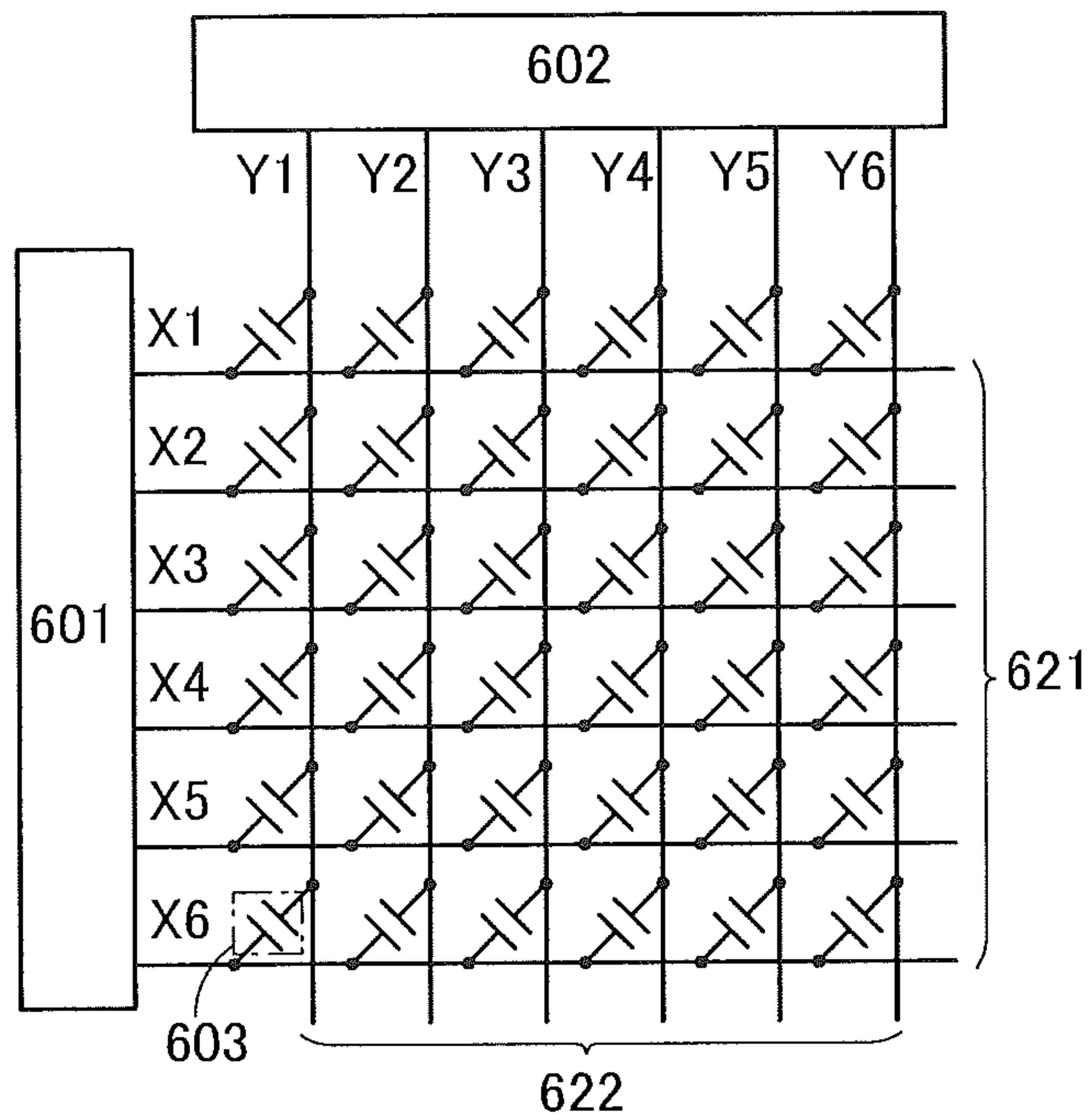


FIG. 19B

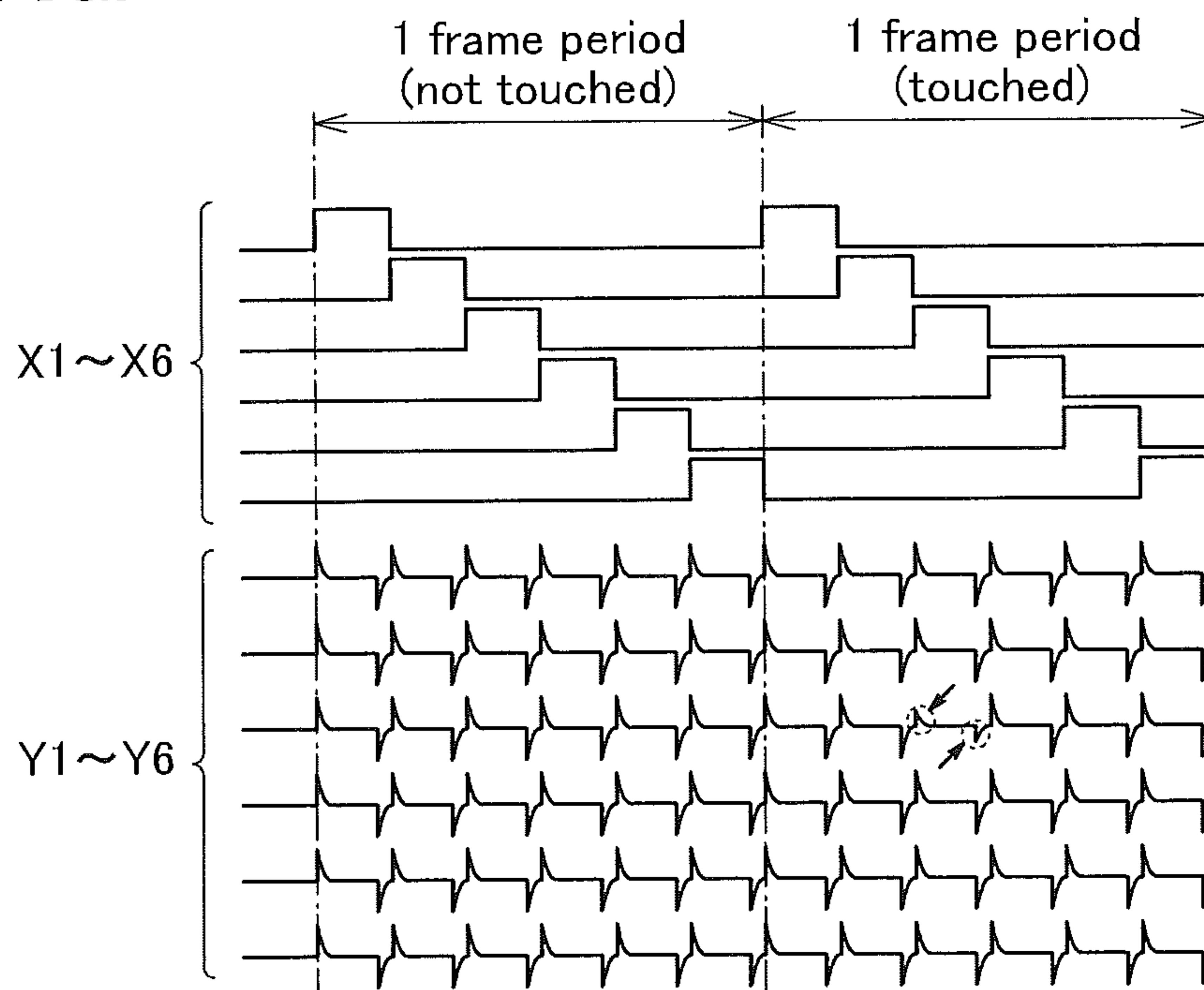




FIG. 21A

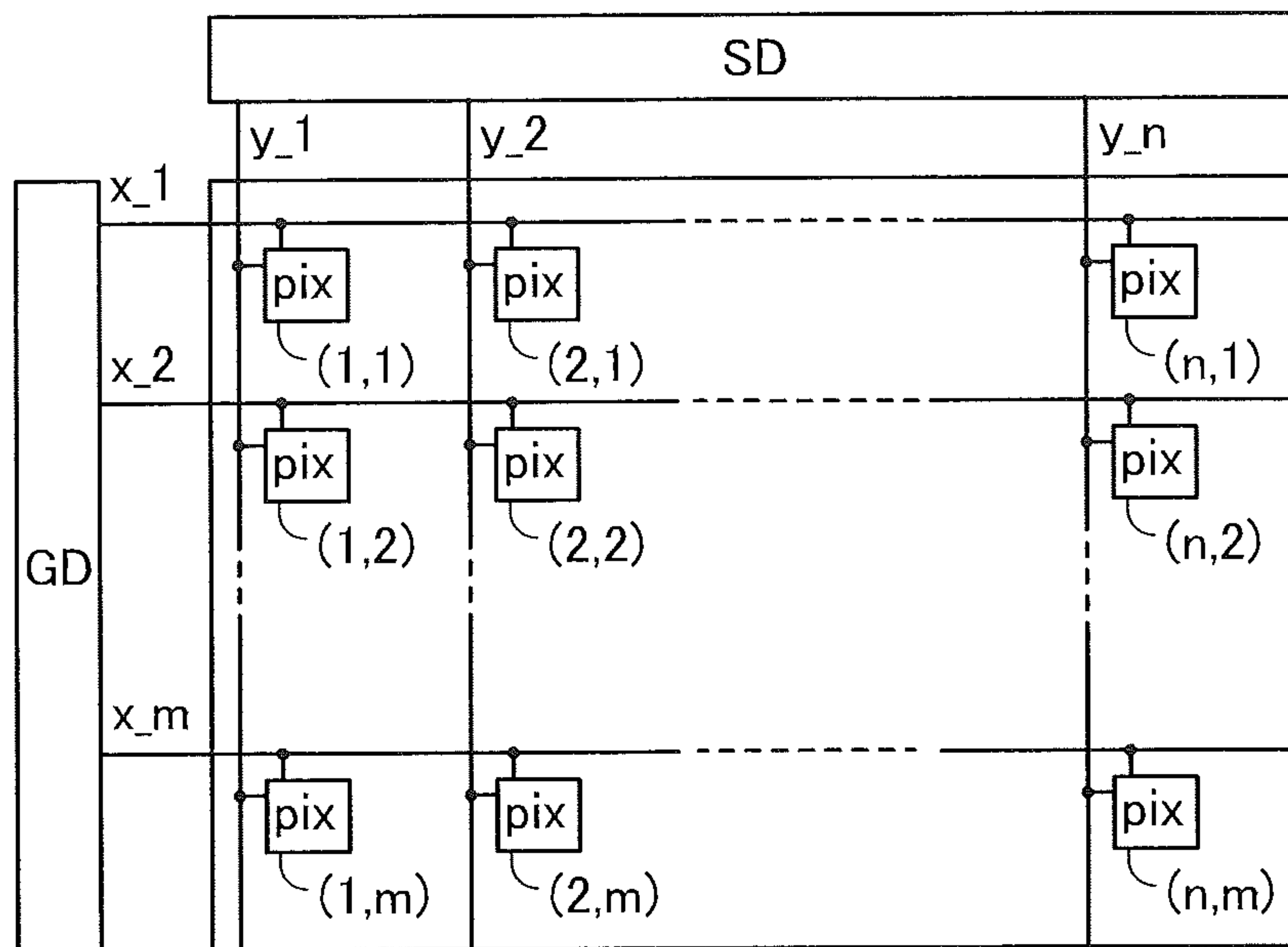


FIG. 21B

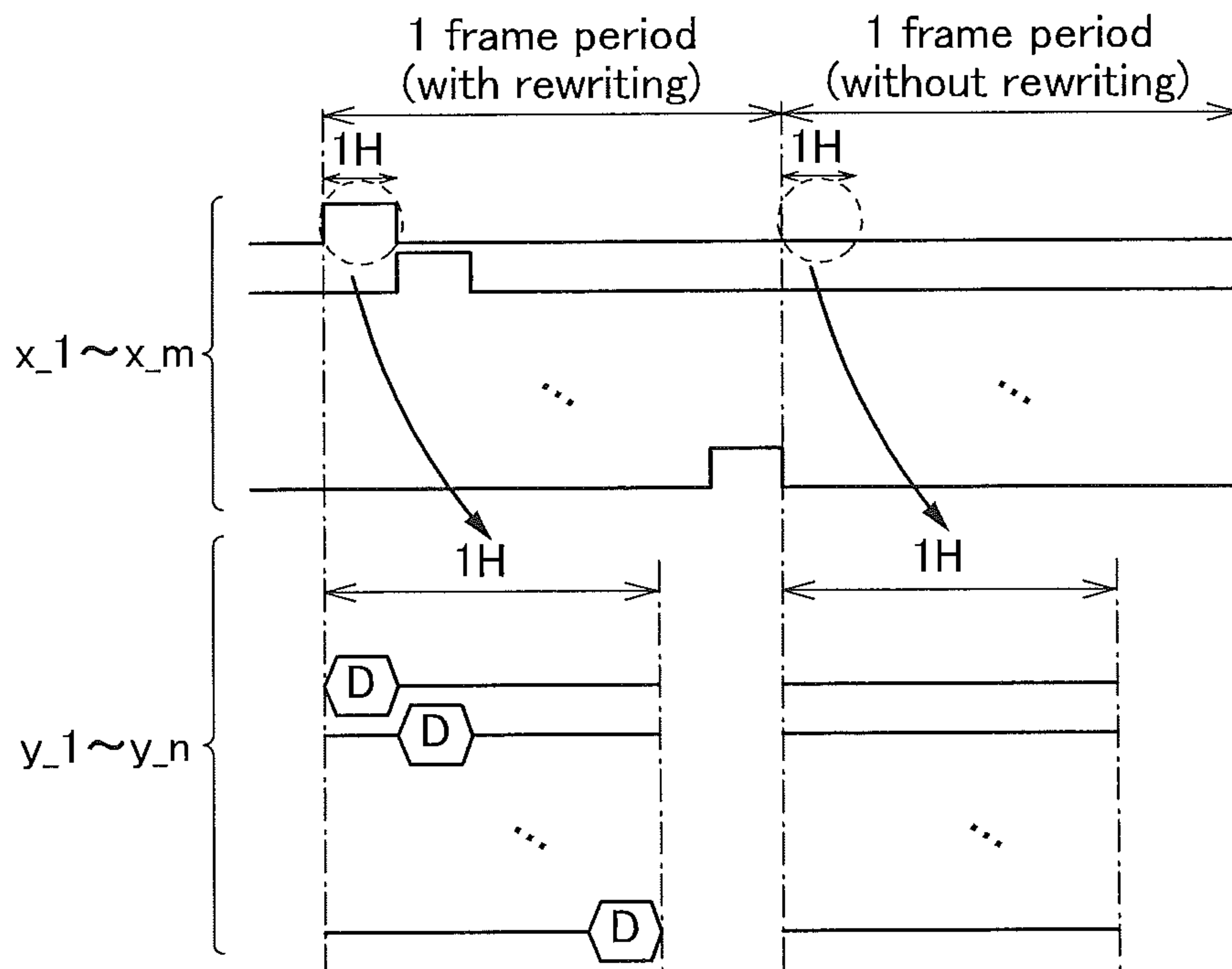




FIG. 22A

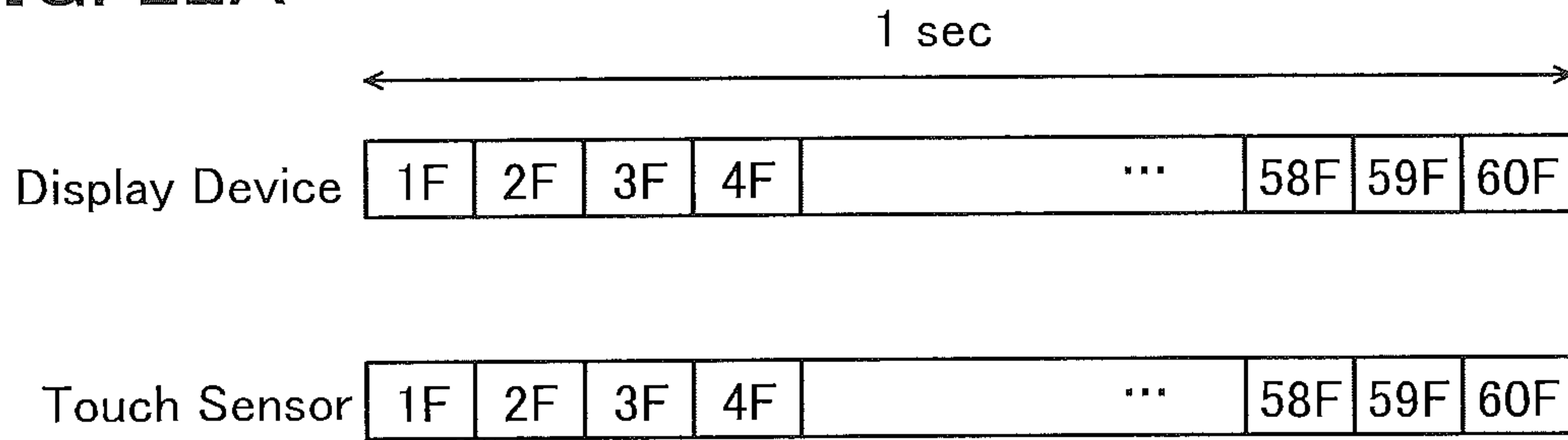


FIG. 22B

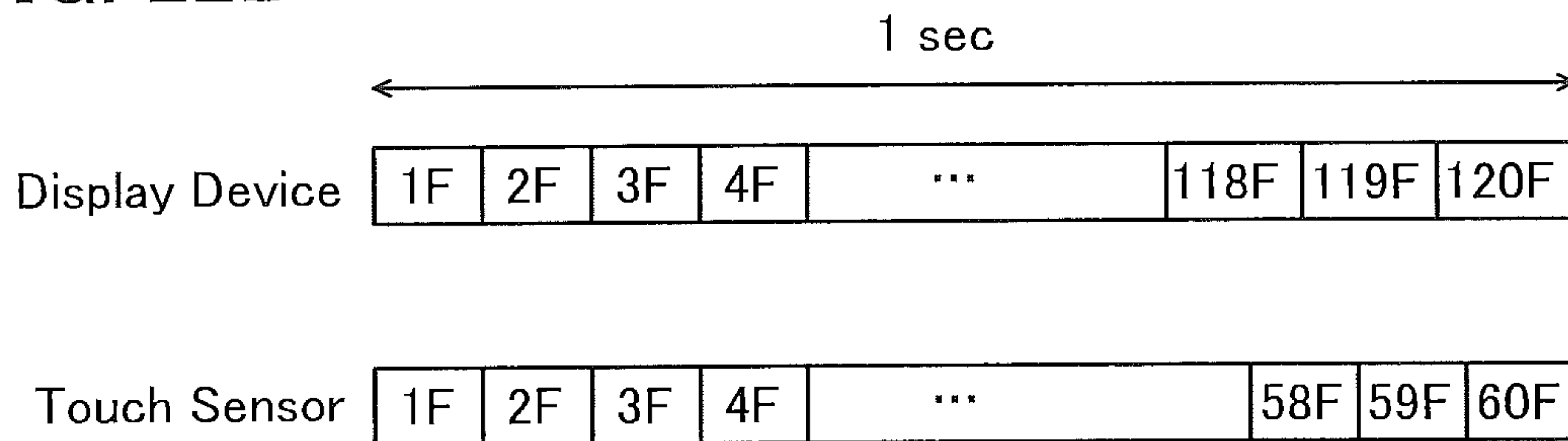


FIG. 22C

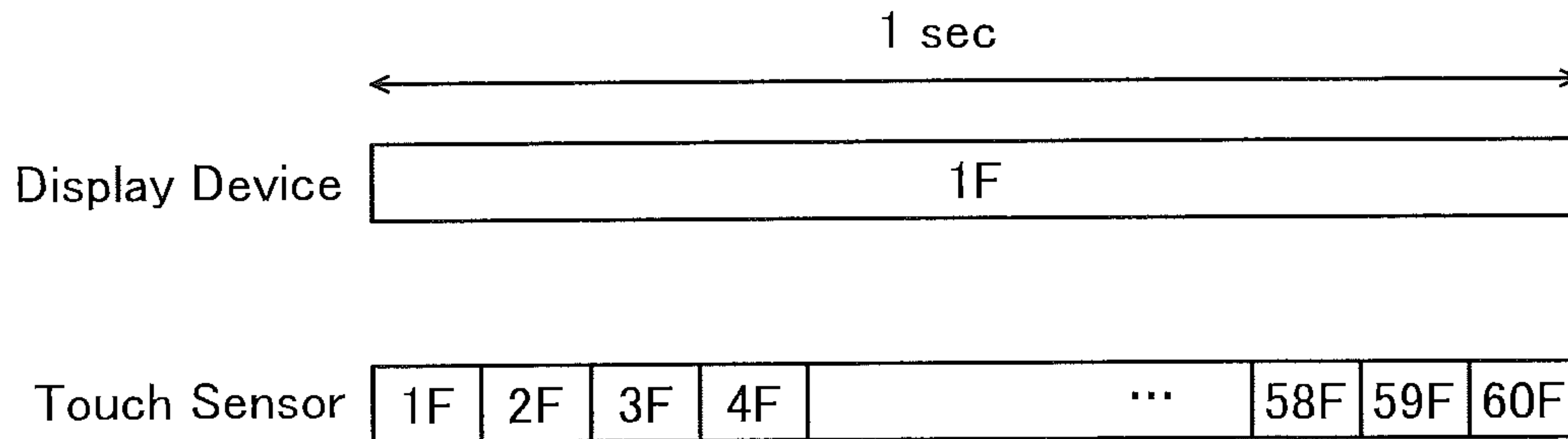


FIG. 22D

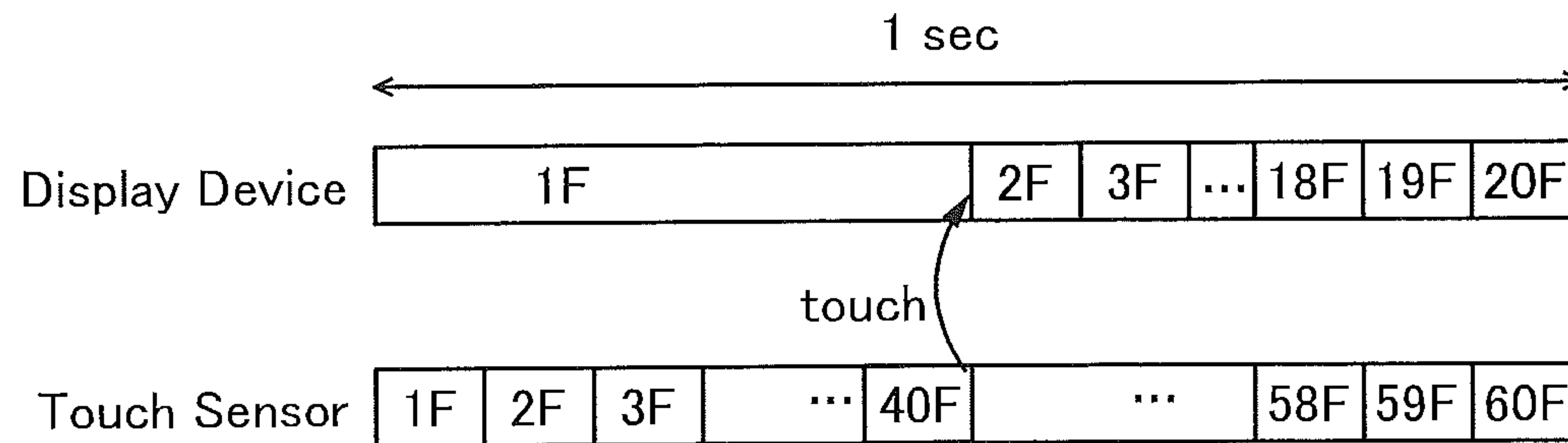






FIG. 24

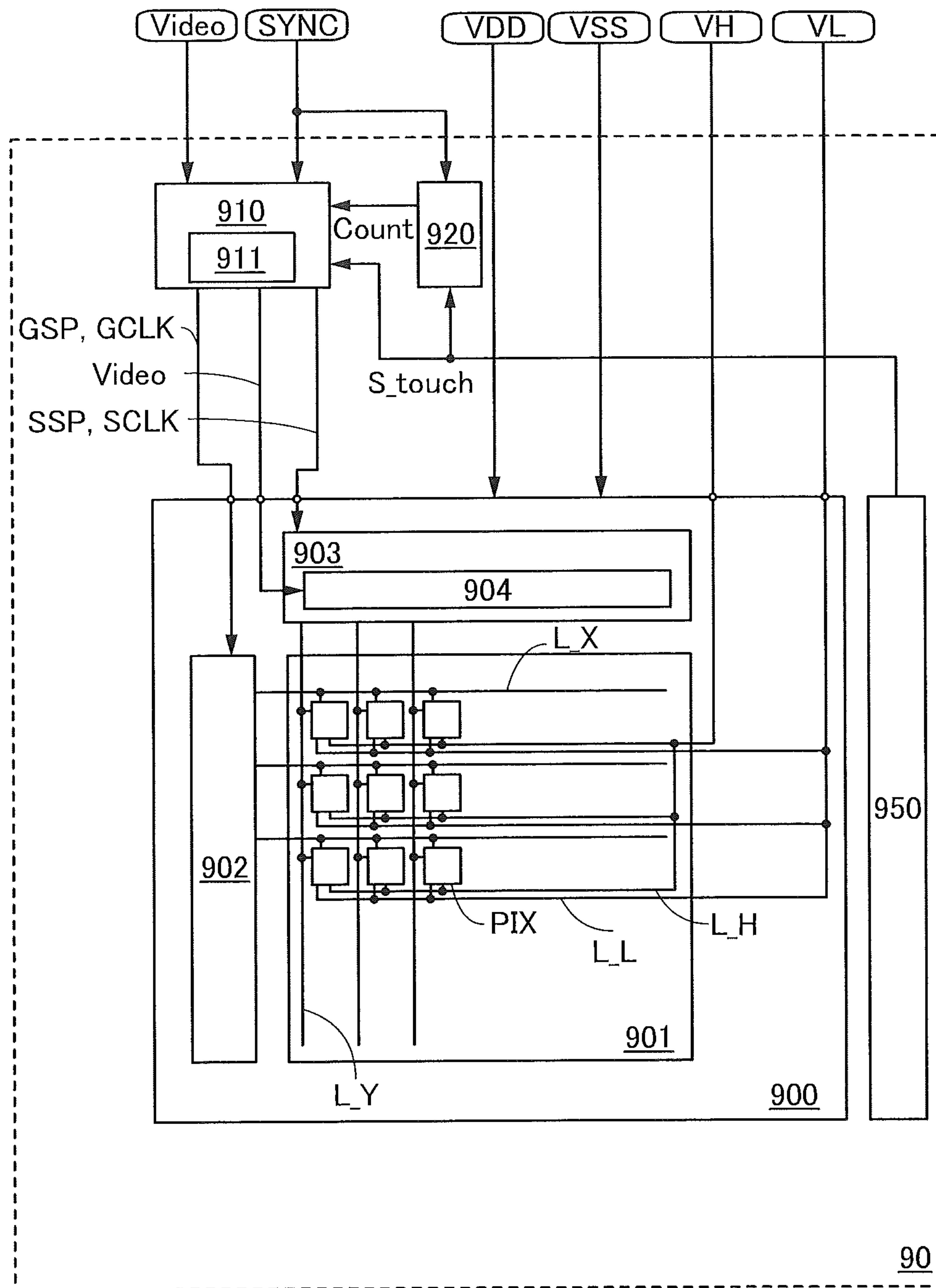


FIG. 25A

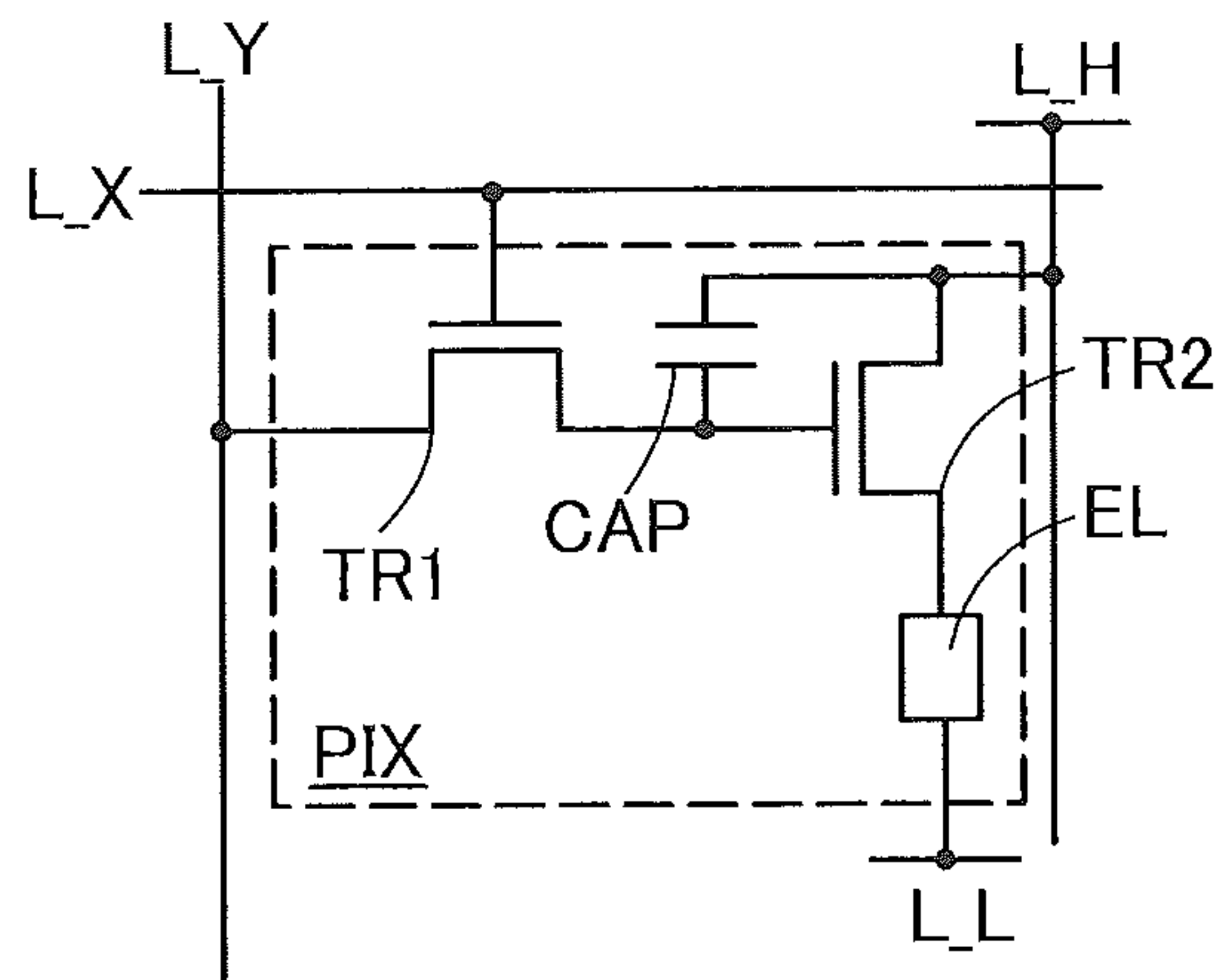


FIG. 25B

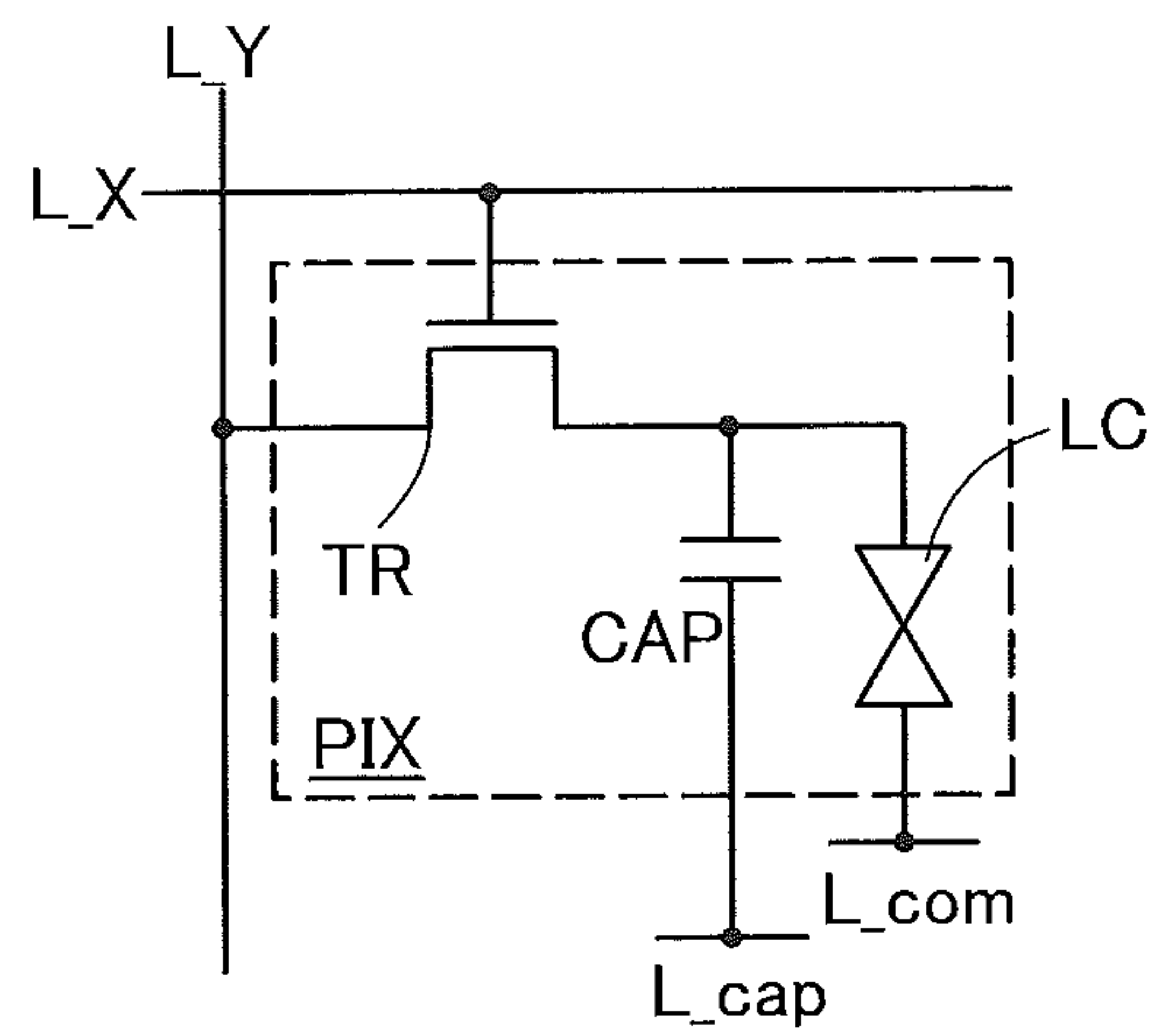
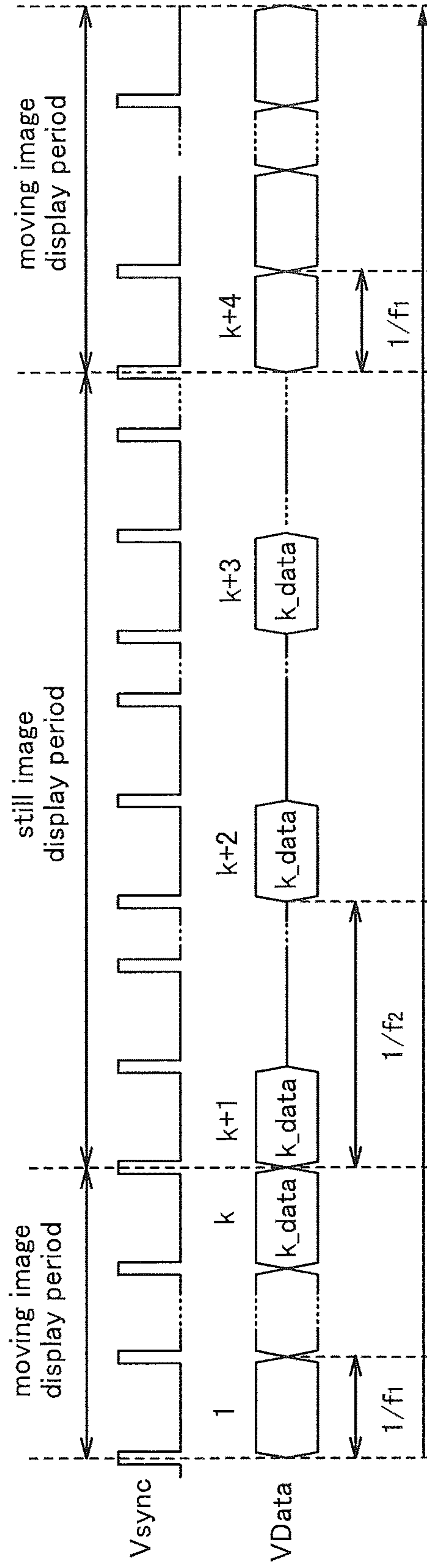




FIG. 26





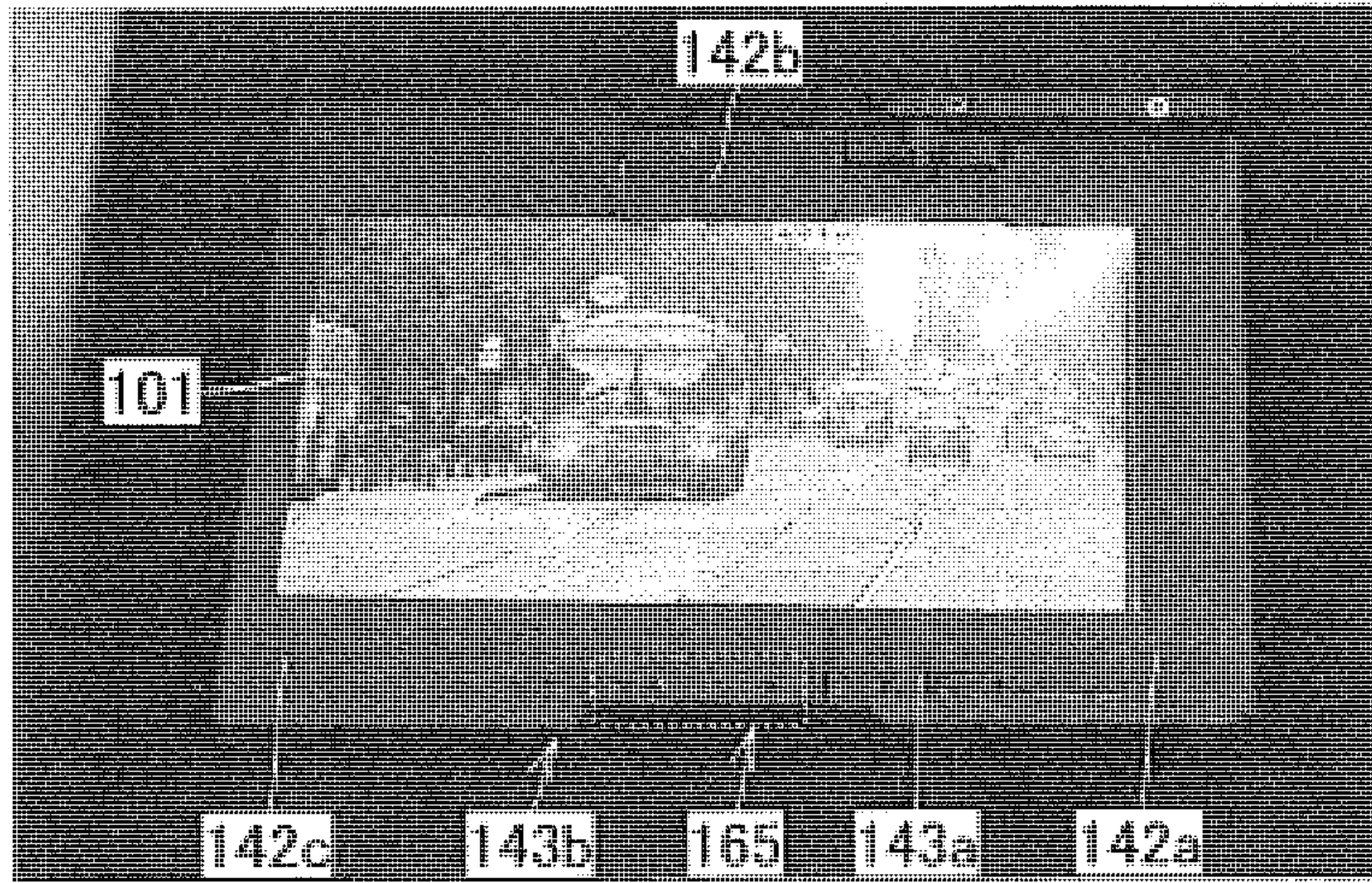


FIG. 27A

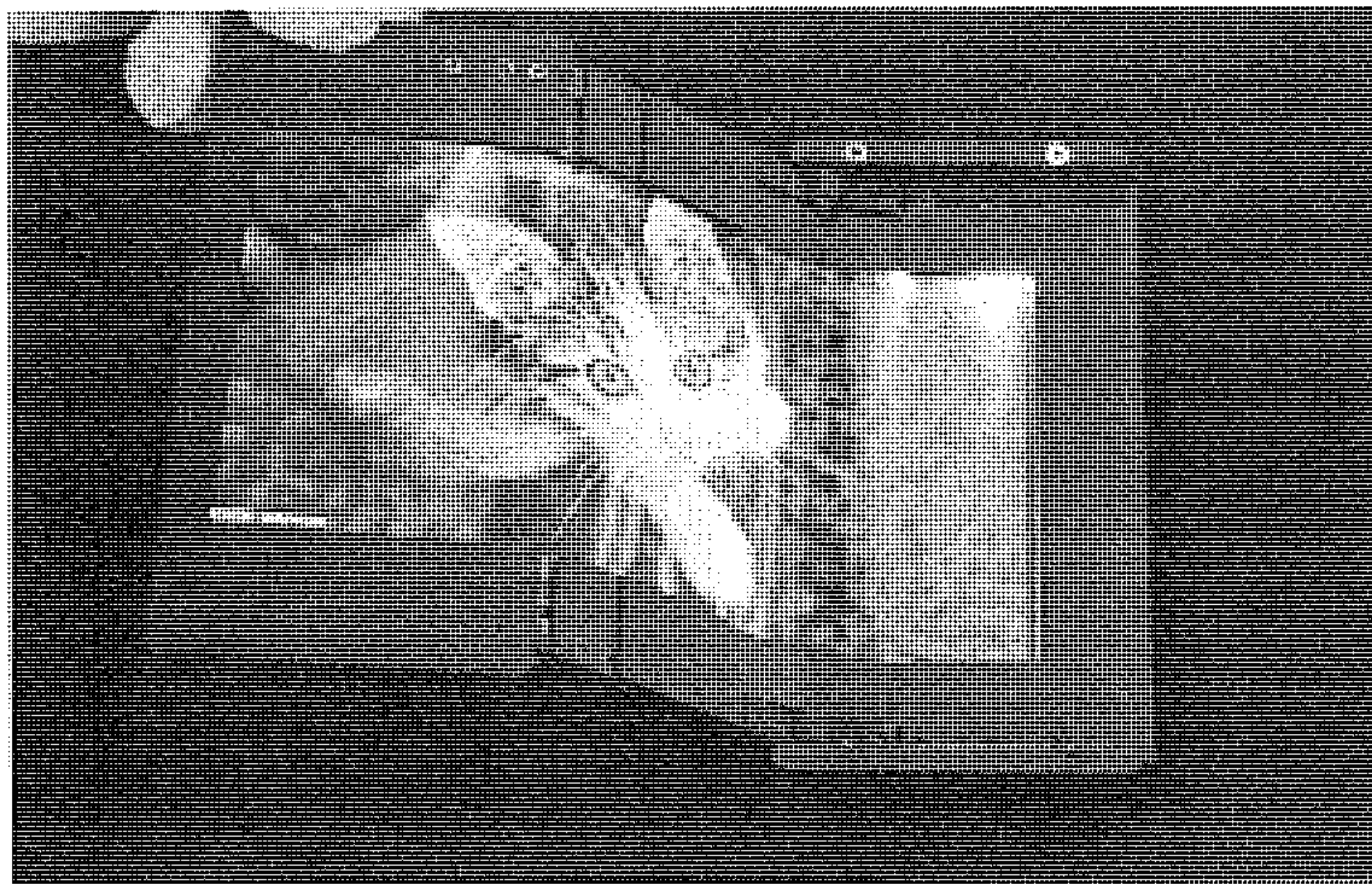


FIG. 27B

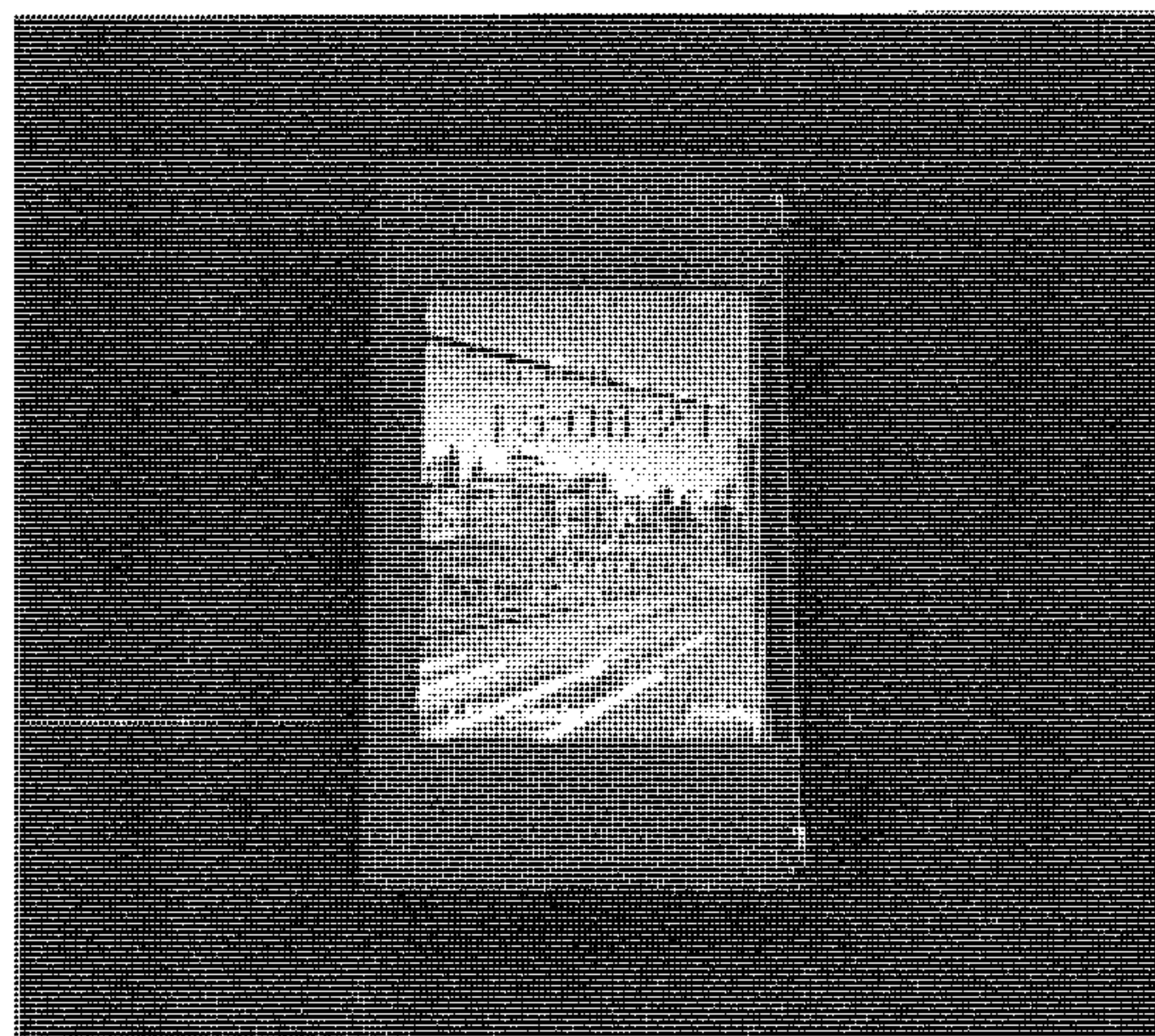


FIG. 27C



**ELECTRONIC DEVICE**

This application is a continuation of copending U.S. application Ser. No. 14/629,990, filed on Feb. 24, 2015 which is incorporated herein by reference.

**BACKGROUND OF THE INVENTION****1. Field of the Invention**

One embodiment of the present invention relates to a display device, and particularly relates to a display device which has flexibility and can be curved. Furthermore, one embodiment of the present invention relates to an electronic device including a display device.

Note that one embodiment of the present invention is not limited to the above technical field. The technical field of one embodiment of the invention disclosed in this specification and the like relates to an object, a method, or a manufacturing method. Another embodiment of the present invention relates to a process, a machine, manufacture, or a composition of matter. Therefore, specifically, examples of the technical field of one embodiment of the present invention disclosed in this specification include a semiconductor device, a display device, a light-emitting device, a lighting device, a power storage device, a memory device, a driving method thereof, and a manufacturing method thereof.

**2. Description of the Related Art**

In recent years, display devices have been expected to be applied to a variety of uses and have become diversified. For example, display devices for use in portable electronic devices and the like are required to be thin, light, or robust, for example. In addition, novel application is required.

In addition, Patent Document 1 discloses a flexible active-matrix light-emitting device in which an organic EL element and a transistor serving as a switching element are provided over a film substrate.

**PRIOR ART REFERENCE****Patent Document**

[Patent Document 1] Japanese Published Patent Application No. 2003-174153

**SUMMARY OF THE INVENTION**

In recent years, browsability of display has been considered to be improved by enlarging display regions of display devices to display a larger amount of data. However, in applications of portable devices, an enlargement of display devices might entail a reduction in portability. For this reason, high browsability of display and high portability are difficult to achieve at the same time.

An object of one embodiment of the present invention is to provide an electronic device with high portability. Another object is to provide an electronic device with high browsability. Another object is to provide an electronic device with high reliability. Another object is to provide a novel display device or electronic device.

Note that the descriptions of these objects do not disturb the existence of other objects. One embodiment of the present invention does not need to achieve all the objects. Objects other than those described above will be apparent from the descriptions of the specification and the like, and objects other than those described above can be derived from the descriptions of the specification and the like.

One embodiment of the present invention is an electronic device which includes a first support body, a second support body, a first hinge, and a display panel, characterized in that the display panel has flexibility; the display panel includes a first display surface and a second display surface; the first hinge has a function of being capable of rotating on a first rotation axis; the first hinge has a function of being capable of connecting the first support body and the second support body to each other; the first support body and the second support body have a function of being capable of relatively rotating on the first rotation axis; the display panel includes a first portion, a second portion, and a third portion; the first portion includes a portion supported by the first support body; the second portion includes a portion supported by the second support body; the third portion includes a portion not fixed to the first support body and the second support body; the first display surface includes a region where the first display surface and the first portion overlap with each other; the second display surface includes a region where the second display surface and the second portion overlap with each other; a first plane includes a region parallel to the first rotation axis; the first plane is positioned on the same plane as the first display surface; the first plane is a plane obtained by extending the first display surface in a direction parallel to the first display surface; the first plane includes a region where the first plane and the first rotation axis overlap with each other; the second plane includes a region parallel to the first rotation axis; the second plane is positioned on the same plane as the second display surface; the second plane is a plane obtained by extending the second display surface in a direction parallel to the second display surface; the second plane includes a region where the second plane and the first rotation axis overlap with each other; a distance between the first plane and the first rotation axis is greater than zero; and a distance between the second plane and the first rotation axis is greater than zero.

In addition, one embodiment of the present invention is an electronic device which includes a first support body, a second support body, a first hinge, and a display panel. The display panel includes a first portion supported by the first support body, a second portion supported by the second support body, and a third portion that is positioned between the first portion and the second portion and has flexibility. The display panel includes a display surface overlapping with the first portion, the second portion, and the third portion. The first hinge has a first rotation axis and has a function of connecting the first support body and the second support body to each other. The first support body and the second support body have a function of relatively rotating on the first rotation axis. It is characterized in that the first rotation axis and a first plane including the display surface overlapping with the first portion are parallel to each other; the first rotation axis and a second plane including the display surface overlapping with the second portion are parallel to each other; a distance between the first plane and the first rotation axis is greater than zero; and a distance between the second plane and the first rotation axis is greater than zero.

In the above, it is preferable that the distance between the first plane and the first rotation axis be greater than or equal to 0.1 mm and less than or equal to 20 mm and the distance between the second plane and the first rotation axis be greater than or equal to 0.1 mm and less than or equal to 20 mm.

In the above, it is also preferable that the distance between the first plane and the first rotation axis and the distance



between the second plane and the first rotation axis be substantially equal to each other.

In the above, it is also preferable that the first support body and the second support body be capable of relatively rotating on the first rotation axis by an angle greater than 180 degrees.

In the above, it is also preferable that the first rotation axis be positioned on a side in a direction of a normal vector to the first display surface when the first plane and the second plane are identical with each other, and that the display panel be foldable so that a third display surface overlapping with the third portion becomes a concave surface. Alternatively, it is preferable that the first rotation axis be positioned on a side opposite to the direction of the normal vector to the first display surface when the first plane and the second plane are identical with each other, and that the display panel be foldable so that the third display surface overlapping with the third portion becomes a convex surface.

In the above, it is also preferable that a third support body and a second hinge be further included; the second hinge have a function of being capable of rotating on a second rotation axis; the second hinge have a function of being capable of connecting the second support body and the third support body to each other; the second support body and the third support body have a function of being capable of relatively rotating on the second rotation axis; the display panel include a fourth portion and a fifth portion; the display panel include a fourth display surface; the fourth portion include a portion supported by the third support body; the fifth portion include a portion not fixed to the second support body and the third support body; the fourth display surface include a region where the fourth display surface and the fourth portion overlap with each other; the second plane include a region parallel to the second rotation axis; a third plane include a region parallel to the second rotation axis; the third plane be positioned on the same plane as the fourth display surface; the third plane be a plane obtained by extending the fourth display surface in a direction parallel to the fourth display surface; the third plane include a region where the third plane and the second rotation axis overlap with each other; a distance between the second plane and the second rotation axis be greater than zero; and a distance between the third plane and the second rotation axis be greater than zero.

Alternatively, it is preferable that a third support body and a second hinge be further included in a structure; the second hinge have a second rotation axis and have a function of connecting the second support body and the third support body to each other; the second support body and the third support body have a function of relatively rotating on the second rotation axis; the display panel include a fourth portion supported by the third support body and a fifth portion that is positioned between the second portion and the fourth portion and has flexibility; the display surface include a portion overlapping with the fourth portion and the fifth portion; the second rotation axis and a third plane including the display surface overlapping with the fourth portion be parallel to each other; the second plane and the second rotation axis be parallel to each other; a distance between the second plane and the second rotation axis be greater than zero; and a distance between the third plane and the second rotation axis be greater than zero.

In the above, it is also preferable that the distance between the second plane and the second rotation axis be greater than or equal to 0.1 mm and less than or equal to 20 mm and the

distance between the third plane and the second rotation axis be greater than or equal to 0.1 mm and less than or equal to 20 mm.

In the above, it is also preferable that the distance between the second plane and the second rotation axis and the distance between the third plane and the second rotation axis be substantially equal to each other.

In the above, it is also preferable that the second support body and the third support body be capable of relatively rotating on the second rotation axis by an angle greater than 180 degrees.

In the above, it is also preferable that the second rotation axis be positioned on a side in a direction of a normal vector to the second display surface when the second plane and the third plane are identical with each other when the second plane and the third plane are identical with each other, and that the display panel be foldable so that a fifth display surface overlapping with the fifth portion becomes a concave surface. Alternatively, it is preferable that the second rotation axis be positioned on a side opposite to the direction of the normal vector to the second display surface when the second plane and the third plane are identical with each other, and that the display panel be foldable so that the fifth display surface overlapping with the fifth portion becomes a convex surface.

An electronic device with high portability can be provided. Alternatively, an electronic device with high browsability can be provided. Alternatively, an electronic device with high reliability can be provided. Alternatively, a novel display device or electronic device can be provided. Note that the descriptions of these effects do not disturb the existence of other effects. Note that one embodiment of the present invention does not necessarily need to have all the above effects. Note that effects other than these will be apparent from the descriptions of the specification, drawings, claims, and the like, and effects other than these can be derived from the descriptions of the specification, drawings, claims, and the like.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A to 1C show structure examples of an electronic device according to an embodiment.

FIGS. 2A to 2C show structure examples of an electronic device according to an embodiment.

FIGS. 3A to 3C show structure examples of an electronic device according to an embodiment.

FIGS. 4A to 4C show structure examples of an electronic device according to an embodiment.

FIGS. 5A to 5C show structure examples of an electronic device according to an embodiment.

FIG. 6 shows a structure example of an electronic device according to an embodiment.

FIGS. 7A to 7C show structure examples of an electronic device according to an embodiment.

FIGS. 8A to 8D show structure examples of an electronic device according to an embodiment.

FIGS. 9A to 9C show structure examples of an electronic device according to an embodiment.

FIGS. 10A to 10B show structure examples of an electronic device according to an embodiment.

FIGS. 11A to 11D show diagrams illustrating examples of light-emitting panels according to an embodiment.

FIGS. 12A to 12E show diagrams illustrating examples of light-emitting panels according to an embodiment.



## 5

FIGS. 13A to 13C show diagrams illustrating a manufacturing method example of a light-emitting panel according to an embodiment.

FIGS. 14A to 14C show diagrams illustrating a manufacturing method example of a light-emitting panel according to an embodiment.

FIGS. 15A to 15C show diagrams illustrating an example of a touch panel according to an embodiment.

FIGS. 16A to 16B show diagrams illustrating an example of a touch panel according to an embodiment.

FIGS. 17A to 17C show diagrams illustrating an example of a touch panel according to an embodiment.

FIGS. 18A to 18C show diagrams illustrating examples of touch panels according to an embodiment.

FIGS. 19A to 19B show a block diagram and a timing chart for a touch sensor according to an embodiment.

FIG. 20 shows a circuit diagram of a touch sensor according to an embodiment.

FIGS. 21A to 21B show a block diagram and a timing chart for a display device according to an embodiment.

FIGS. 22A to 22D show diagrams illustrating operations of a display device and a touch sensor according to an embodiment.

FIGS. 23A to 23D show diagrams illustrating operations of a display device and a touch sensor according to an embodiment.

FIG. 24 shows a block diagram of a touch panel according to an embodiment.

FIGS. 25A to 25B show circuit diagrams of pixels according to an embodiment.

FIG. 26 shows a timing chart illustrating operation of a display device according to an embodiment.

FIGS. 27A to 27C show photographs of an electronic device according to an example.

#### DETAILED DESCRIPTION OF THE INVENTION

Embodiments will be described in detail with reference to drawings. Note that the present invention is not limited to the following description, and it will be easily understood by those skilled in the art that various changes can be made without departing from the spirit and scope of the present invention. Therefore, the present invention should not be construed as being limited to the description in the following embodiments.

Note that in the structures of the invention described below, the same portions or portions having similar functions are denoted by the same reference numerals in different drawings, and repetitive description thereof is omitted. Furthermore, the same hatch pattern is applied to similar functions, and these are not especially denoted by reference numerals in some cases.

Note that in each drawing described in this specification, the size, the layer thickness, or the region of each component is exaggerated for clarity in some cases. Therefore, it is not necessarily limited to such scales.

Note that ordinal numbers such as “first” and “second” in this specification and the like are used in order to avoid confusion among components, and do not limit the components numerically.

Note that in this specification and the like, a plane A being parallel to a plane B means a state in which an angle between a normal to the plane A and a normal to the plane B is greater than or equal to  $-20^\circ$  and less than or equal to  $20^\circ$ . In addition, in this specification and the like, a plane C being perpendicular to the plane B means a state in which an angle

## 6

between a normal to the plane C and the normal to the plane B is greater than or equal to  $70^\circ$  and less than or equal to  $110^\circ$ . In addition, in this specification and the like, a line D being perpendicular to the plane B means a state in which an angle between the line D and the normal to the plane B is greater than or equal to  $-20^\circ$  and less than or equal to  $20^\circ$ . In addition, in this specification and the like, a line E being parallel to the plane B means a state in which an angle between the line E and the normal to the plane B is greater than or equal to  $70^\circ$  and less than or equal to  $110^\circ$ .

#### Embodiment 1

In this embodiment, a structure example of an electronic device in one embodiment of the present invention will be described with reference to drawings.

#### Structure Example 1

FIG. 1A is a perspective view of an electronic device 100 described in this structure example. The electronic device 100 includes a display panel 101, a support body 102a, a support body 102b, and a hinge 103.

The support body 102a and the support body 102b are connected by the hinge 103. The support body 102a and the support body 102b can be relatively rotated on a rotation axis 111 of the hinge 103. In the structure example illustrated in FIG. 1A, the support body 102a and the support body 102b can be relatively rotated on the rotation axis 111 by an angle greater than or equal to  $180^\circ$  from a state where the support body 102a and the support body 102b are set horizontal.

Here, the rotation axis 111 of the hinge 103 refers to a straight line corresponding to a rotation axis of a rotation mechanism of the hinge 103. For example, in the case where the hinge 103 has a mechanism to rotate on an axis of a spindle or the like that is a tangible object, a straight line corresponding to an extending direction of the axis is the rotation axis 111.

The display panel 101 includes a display surface where an image or the like to be viewed by a user is displayed. Note that in this specification and the like, the display surface refers to a surface of a display panel on a side where an image or the like is displayed.

The display panel 101 has flexibility at least partly. Therefore, the display panel 101 can be reversibly changed in shape from a state where the display surface is planar into a state where it has a curved surface. The display panel 101 has flexibility at least in a portion which is changed in shape with a change in the relative position of the two support bodies, and does not necessarily have flexibility in other portions.

Furthermore, part of the display panel 101 is supported by the support body 102a and another part thereof is supported by the support body 102b.

The electronic device 100 of one embodiment of the present invention has a structure in which the display panel 101 having flexibility is supported by two support bodies. The display panel 101 can be changed in shape by bending or the like. For example, the display panel 101 can be bent so that the display surface faces inward (bent inward). The display panel 101 can also be folded by bending. The electronic device 100 of one embodiment of the present invention has high portability with the display panel 101 folded, and has high browsability with a seamless large display region in an opened state.



FIG. 1B is a schematic diagram illustrating each region (also referred to as portion) of the display panel 101. The display panel 101 has a portion 101a supported by the support body 102a in a portion overlapping with the support body 102a. In addition, the display panel 101 has a portion 101b supported by the support body 102b in a portion overlapping with the support body 102b. Furthermore, the display panel 101 has a portion 101c not fixed to either of the support bodies between the portion 101a and the portion 101b.

In the portion 101a, the display panel 101 is preferably supported by the support body 102a such that the display surface of the display panel 101 is planar. Similarly, in the portion 101b, the display panel 101 is preferably supported by the support body 102b such that the display surface of the display panel 101 is horizontal.

In addition, the display panel 101 is preferably supported by each support body so as to slide in a direction parallel to a bending direction. For example, the display panel 101 is preferably supported by each support body such that its position in the thickness direction is fixed. At this time, it is preferable that the display panel 101 can slide in the bending direction of the directions parallel to the display surface and its position in a direction perpendicular thereto be fixed. By using such a supporting method, when the support bodies are relatively rotated from a state in which the display panel 101 is set planar into a state in which it is bent by 180°, a slight difference in the length of the display panel 101 between the two states can be corrected by the slide operation, whereby damage to the display panel 101 can be reduced. Alternatively, one of the plurality of support bodies and the display panel 101 may be fixed to each other such that the display panel 101 does not slide. Furthermore, part of the display panel 101 may have elasticity. Expansion and contraction of part of the display panel 101 can correct the above difference in length. Furthermore, the display panel 101 may be fixed to each support body such that the portion 101c of the display panel 101 loosens in the state where the display panel 101 is opened. By the looseness of the display panel 101, the above difference in length can be corrected.

A method for supporting the display panel 101 with each support body is not particularly limited. For example, by using a method in which the display panel 101 is sandwiched between two members that are processed such that grooves in which the display panel 101 can be fitted are formed, the display panel 101 can be supported so as to slide. In the case where the display panel 101 and each support body are fixed to each other, examples include an attaching method, a fixing method with screws or the like, a mechanically fixing method in which the display panel 101 is sandwiched between members, and the like.

In addition, the areas of the portion 101a and the portion 101b are not particularly limited, and the display panel 101 includes at least two regions supported by respective support bodies and one or more regions not supported by (fixed to) either of the support bodies therebetween. For example, the display panel 101 may be supported in a region overlapping with an edge of each support body, and the entire visible region may be the portion 101c not supported by the support bodies.

FIG. 1C is a schematic cross-sectional view along cutting-plane line A1-A2 in FIG. 1A. In addition, in FIG. 1C, the hinge 103 is indicated by a broken line in order to show the positional relationship between each component and the hinge 103.

Each of FIGS. 1A to 1C illustrates the case where the support body 102a and the support body 102b are positioned

so that the entire display surface of the display panel 101 is set planar, in other words, the case where a first plane 110a including the display surface in the portion 101a of the display panel 101 and a second plane 110b including the display surface in the portion 101b of the display panel 101 are parallel to each other.

At this time, the rotation axis 111 of the hinge 103 is provided so as to overlap with the portion 101c of the display panel 101 (i.e., so as to be positioned over the portion 101c). Furthermore, as illustrated in FIG. 1C, a distance between the rotation axis 111 and the display surface is preferably provided so as to be apart from each other by a distance  $r_0$  to prevent the rotation axis 111 of the hinge 103 and the display surface of the display panel 101 from corresponding to each other (i.e., to prevent the rotation axis 111 from being positioned in a plane including the display surface). That is, the hinge 103 is preferably provided so that each of the distance between the first plane 110a and the rotation axis 111 and the distance between the second plane 110b and the rotation axis 111 has a value greater than zero. Furthermore, when the first plane 110a and the second plane 110b are identical with each other (i.e., positioned on the same plane), the rotation axis 111 is provided on a display surface side of the display panel 101 (specifically, a side in a direction of a normal vector to the display surface) so as to be in a position apart from the display surface.

Furthermore, as illustrated in FIG. 1C, it is preferable that the display surface of the display panel 101 and the rotation axis 111 be parallel to each other. That is, it is preferable that the first plane 110a and the rotation axis 111 be parallel to each other and the second plane 110b and the rotation axis 111 be parallel to each other.

Note that there may be a case where a plane including the display surface (here, a plane including the first plane 110a and the second plane 110b) and the rotation axis 111 are not exactly parallel to each other when the display surface of the display panel 101 is set planar. At this time, it is acceptable as long as the first plane 110a or the second plane 110b and the rotation axis 111 do not intersect with each other at least in a region overlapping with the display surface of the display panel 101. Note that in the case where the plane including the display surface and the rotation axis 111 are not exactly parallel to each other (i.e., in the case where the angle between the normal direction to the display surface and the rotation axis 111 is not exactly 90°), the distance  $r_0$  between the rotation axis 111 and the display surface (or the first plane 110a or the second plane 110b) can be a distance  $r_0$  having the smallest value between the display surface (or the first plane 110a or the second plane 110b) and a line overlapping with the display surface of the display panel 101 on a straight line including the rotation axis 111.

FIG. 2A is a schematic perspective view of the electronic device 100 in a state where the support body 102b is rotated on the rotation axis 111 by 180° to the support body 102a. In addition, FIG. 2B is a schematic cross-sectional view along cutting-plane line B1-B2 in FIG. 2A. Furthermore, FIG. 2C is an enlarged schematic cross-sectional view of a region enclosed by a broken line in FIG. 2B.

As illustrated in FIGS. 2B and 2C, the display panel 101 has a portion where the display surface in the portion 101c is curved by 180° so as to be concave. In addition, the first plane 110a including part of the display surface in the portion 101a of the display panel 101 and the plane 110b including part of the display surface in the portion 101b are parallel to each other.



At this time, the distance between the first plane **110a** and the rotation axis **111** and the distance between the second plane **110b** and the rotation axis **111** are preferably set to the same distance ( $r_0$ ). When these distances are equal, the entire display surface of the display panel **101** can be set flat (planar) with no step (level difference) generated on the surface of the display panel **101** positioned between the support body and the support body, in a state where the two support bodies are opened as illustrated in FIGS. **1A** to **1C**. Accordingly, the electronic device **100** with high visibility can be realized.

Part of the portion **101c** of the display panel **101** is curved depending on the angle made by the two support bodies. Furthermore, each of the two support bodies rotates on the rotation axis **111** while being supported by the hinge **103**. Therefore, the direction of force to which the portion **101c** of the display panel **101** is subjected when the angle between the two support bodies is changed is a direction parallel to the rotation direction of the support bodies, in other words, a direction perpendicular to a contact surface between each support body and the display panel **101**. That is, most components of force applied to the portion **101c** of the display panel **101** are in a direction parallel to the thickness direction of the display panel **101**, that is, a direction in which the display panel **101** is curved. Therefore, the display panel **101** is not subjected to excessive force; thus, damage to the curved portion of the display panel **101** can be effectively reduced.

In addition, as illustrated in FIG. **2C**, when the first plane **110a** and the second plane **110b** are parallel to each other, the curvature radius  $r_1$  of the curved portion of the display panel **101** is substantially equal to the distance  $r_0$ .

FIG. **3A** is a schematic perspective view of the electronic device **100** in a state where the support body **102b** is rotated on the rotation axis **111** by an angle greater than  $180^\circ$  to the support body **102a**. In addition, FIG. **3B** is a schematic cross-sectional view along cutting-plane line C1-C2 in FIG. **3A**. Furthermore, FIG. **3C** is an enlarged schematic cross-sectional view of a region enclosed by a broken line in FIG. **3B**.

Each of FIGS. **3A** to **3C** illustrates a state where the support body **102a** and the support body **102b** are rotated such that respective end portions of the two support bodies on sides opposite to the hinge **103** are in contact with each other.

As illustrated in FIG. **3C**, when the two support bodies are rotated by an angle greater than  $180^\circ$  from a state where the display panel **101** is set flat, the curvature radius  $r_1$  of the portion **101c** of the display panel **101** is smaller than the distance  $r_0$  between the first plane **110a** (or the second plane **110b**) and the rotation axis **111** of the hinge **110**.

Here, the curvature radius  $r_1$  of the curved portion of the display panel **101** refers to a curvature radius of the curved display surface which has the smallest value.

As the angle of rotation from the state where the display panel **101** is set flat increases, the value of the curvature radius  $r_1$  with respect to the distance  $r_0$  decreases. For example, the curvature radius  $r_1$  at a rotation angle of  $185^\circ$  is approximately 0.93 times the distance  $r_0$ , the curvature radius  $r_1$  at a rotation angle of  $190^\circ$  is approximately 0.87 times the distance  $r_0$ , and the curvature radius  $r_1$  at a rotation angle of  $195^\circ$  is approximately 0.82 times the distance  $r_0$ .

When the angle of rotation from the state where the display panel **101** is set flat is greater than  $180^\circ$ , the thickness of the electronic device **100** in a state where the two support bodies are folded can be partially small; thus, the electronic device with high portability can be realized.

For example, the maximum value of the rotation angle may be set in a range greater than  $180^\circ$  and less than or equal to  $200^\circ$ , preferably greater than  $180^\circ$  and less than or equal to  $195^\circ$ , more preferably greater than  $180^\circ$  and less than or equal to  $190^\circ$ .

Damage to the curved portion of the display panel **101** can be reduced by setting the distance  $r_0$  between the first plane **110a** (or the second plane **110b**) and the rotation axis **111** of the hinge **110** in view of the maximum value of the rotation angle and the minimum curvature radius allowable to the display panel **101**.

For example, when the distance between the first plane **110a** and the rotation axis **111** and the distance between the second plane **110b** and the rotation axis **111** are equal to each other and are each  $r_0$ , the value of  $r_0$  is preferably set larger than or equal to 0.1 mm and smaller than or equal to 20 mm, preferably larger than or equal to 0.5 mm and smaller than or equal to 15 mm, more preferably larger than or equal to 1 mm and smaller than or equal to 10 mm, and is typically preferably set to 4 mm. As  $r_0$  decreases, the thickness of the electronic device **100** in the state where the support bodies are folded can be reduced; thus, the electronic device **100** with high portability can be realized.

Furthermore, the thickness of the display panel **101** is preferably larger than or equal to  $5\ \mu\text{m}$  and smaller than or equal to  $2000\ \mu\text{m}$ , preferably larger than or equal to  $5\ \mu\text{m}$  and smaller than or equal to  $1000\ \mu\text{m}$ , more preferably larger than or equal to  $10\ \mu\text{m}$  and smaller than or equal to  $500\ \mu\text{m}$ , further preferably larger than or equal to  $20\ \mu\text{m}$  and smaller than or equal to  $300\ \mu\text{m}$ . As the thickness of the display panel **101** decreases, the minimum allowable curvature radius can be decreased; thus, the thickness of the electronic device **100** can be decreased.

In the case where the display panel **101** is too thin to have a sufficient mechanical strength, the strength may be supplemented by attaching a sheet having flexibility or the like to at least the curving portion of the display panel **101**. For example, besides an elastic body of hard rubber or the like, plastic, a metal such as aluminum, an alloy such as stainless steel or a titanium alloy, rubber such as silicone rubber, or the like can be used. A material having lower flexibility than the display panel **101** is preferably used for the sheet. In the case where the sheet does not have a light transmitting property, it may be placed on a back surface side of the display panel **101** or in a region outside a display region of the display surface. A structure may be employed in which a sheet having an opening in a portion overlapping with the display surface is placed on a display surface side and the display panel is sandwiched between two sheets.

The curvature radius  $r_1$  in the state where the two support bodies are folded, i.e., a state where the curved portion of the display panel **101** is curved with the smallest curvature radius, is preferably set larger than or equal to 0.1 mm and smaller than or equal to 20 mm, preferably larger than or equal to 0.5 mm and smaller than or equal to 15 mm, more preferably larger than or equal to 1 mm and smaller than or equal to 10 mm, and is typically preferably set smaller than or equal to 4 mm.

Here, a module including a touch sensor is preferably provided by being stacked on the display surface side of the display panel **101**. At this time, it is preferable that at least part of the module including the touch sensor have flexibility and can be curved along the display panel **101**. At this time, the module including the touch sensor and the display panel **101** may be attached to each other with an adhesive or the like, or a polarizing plate or a buffer material (separator) may be provided therebetween. In addition, the thickness of the



## 11

module including the touch sensor is preferably smaller than or equal to the thickness of the display panel 101.

Alternatively, the display panel 101 may function as a touch panel. For example, a structure of an on-cell touch panel or an in-cell touch panel may be employed as the display panel 101. By using the structure of the on-cell or in-cell touch panel, the thickness can be reduced even when the function of a touch panel is added to the display panel 101.

In addition, the structure of the hinge 103 is not limited to the structure illustrated in FIGS. 1A to 1C or the like, and ones in a variety of modes can be used. Furthermore, part of the support body 102a or the support body 102b may have a mode of functioning as the hinge 103. Moreover, although a pair of hinges 103 are provided in the structure of FIGS. 1A to 1C or the like, one hinge or three or more hinges may be provided.

Note that electronic components, for example, a battery, a printed wiring board on which a variety of ICs such as an arithmetic device and a driver circuit are mounted, a wireless receiver, a wireless transmitter, a wireless power receiver, and a variety of sensors such as an acceleration sensor are incorporated as appropriate into one of the support body 102a and the support body 102b, or both, so that the electronic device 100 can function as a portable terminal, a portable image reproducing device, a portable lighting device, or the like. A camera, a speaker, a variety of input/output terminals such as a power supply terminal and a signal supply terminal, a variety of sensors such as an optical sensor, an operation button, or the like may also be incorporated into one of the support body 102a and the support body 102b, or both.

The above is the description of the structure example 1.

## Structure Example 2

A structure example of an electronic device 120 whose structure is partly different from the above structure example 1 will be described below. Note that description of portions overlapping with those in the structure example 1 may be omitted in some cases.

FIG. 4A is a perspective view of a display surface side of the electronic device 120, and FIG. 4B is a perspective view of a back surface side. In addition, FIG. 4C is a schematic cross-sectional view along cutting-plane line D1-D2 in FIG. 4A.

The electronic device 120 differs from the electronic device 100 exemplified in the above structure example 1 mainly in that the position of the hinge 103 is different and in that the shapes of the support body 102a and the support body 102b are different.

The electronic device 120 of one embodiment of the present invention has a structure in which the display panel 101 having flexibility is supported by two support bodies. The display panel 101 can be changed in shape by bending or the like. For example, the display panel 101 can be bent so that a display surface faces outward (bent outward). The display panel 101 can also be folded by bending. The electronic device 120 of one embodiment of the present invention has high portability with the display panel 101 folded, and has high browsability of display with a seamless large display region in an opened state.

The hinge 103 is provided such that the rotation axis 111 thereof is positioned on a side opposite to the display surface of the display panel 101. In a structure illustrated in FIGS. 4A to 4C, the hinge 103 is provided on a side opposite to surfaces of the support body 102a and the support body 102b

## 12

where the display panel 101 is provided. Furthermore, when the first plane 110a including the display surface in the portion 101a of the display panel 101 and the second plane 110b including the display surface in the portion 101b of the display panel 101 are identical with each other, the rotation axis 111 is provided on a side opposite to the display surface of the display panel 101 (specifically, a side opposite to a direction of a normal vector to the display surface) so as to be in a position apart from the display surface.

In addition, the support body 102a and the support body 102b have a cut-out portion at least in a region overlapping with the portion 101c of the display panel 101. In FIG. 4C, a portion overlapping with the support body 102a of the display panel 101 is the portion 101a, a portion overlapping with the support body 102b is the portion 101b, and a portion overlapping with the cut-out portion is the portion 101c. Note that the entire portion overlapping with the support body 102a (or the support body 102b) in the display panel 101 does not need to be supported by the support body 102a (or the support body 102b) and it is acceptable as long as it is partly supported as in the structure example 1.

The support body 102a and the support body 102b can be relatively rotated on the rotation axis 111 by an angle greater than or equal to 180° so that the display surface in the portion 101c of the display panel 101 becomes convex.

FIG. 5A is a schematic perspective view of the electronic device 120 in a state where the support body 102b is rotated on the rotation axis 111 by 180° to the support body 102a. In addition, FIG. 5B is a schematic cross-sectional view along cutting-plane line E1-E2 in FIG. 5A. Furthermore, FIG. 5C is an enlarged schematic cross-sectional view of a region enclosed by a broken line in FIG. 5B.

As illustrated in each of FIGS. 5A to 5C, the display panel 101 is curved such that part of the display surface in the portion 101c is changed in shape so as to be convex. At this time, the cut-out portion provided in the support body 102a and the support body 102b allows the display panel 101 to be curved without physical interference of the display panel 101 and each support body with each other.

Note that a structure may be employed in which back surface sides of the support body 102a and the support body 102b are in contact with each other when the display panel 101 is bent 180° as illustrated in FIG. 6.

FIG. 7A is a schematic perspective view of the electronic device 120 in a state where the support body 102b is rotated on the rotation axis 111 by an angle greater than 180° to the support body 102a. In addition, FIG. 7B is a schematic cross-sectional view along cutting-plane line F1-F2 in FIG. 7A. Furthermore, FIG. 7C is an enlarged schematic cross-sectional view of a region enclosed by a broken line in FIG. 7B.

When the two support bodies are thus rotated by an angle greater than 180° from a state where the display panel 101 is set flat, the thickness of the electronic device 120 in a state where the two support bodies are folded can be partially small; thus, the electronic device with high portability can be realized.

As illustrated in FIG. 7C, when the two support bodies are rotated by an angle greater than 180° from the state where the display panel 101 is set flat, the curvature radius  $r_1$  of the portion 101c of the display panel 101 is smaller than the distance  $r_0$  between the first plane 110a (or the second plane 110b) and the rotation axis 111 of the hinge 110.

The above is the description of the structure example 2.

## Structure Example 3

A structure example of an electronic device 130 whose structure is partly different from the above structure example



## 13

will be described below. Note that description of portions overlapping with those in the above structure example may be omitted in some cases.

FIG. 8A is a perspective view of a display surface side of the electronic device 130, and FIG. 8B is a perspective view of a back surface side.

The electronic device 130 differs mainly in including a support body 102c in addition to the electronic device 120 exemplified in the structure example 2.

The support body 102a and the support body 102b are connected to each other by a hinge 103a. The support body 102b and the support body 102c are connected to each other by a hinge 103b. The display panel 101 includes regions supported by the support body 102a, the support body 102b, and the support body 102c, respectively. In addition, the display panel 101 includes regions not supported by the support bodies between the region supported by the support body 102a and the region supported by the support body 102b and between the region supported by the support body 102b and the region supported by the support body 102c.

The electronic device 130 of one embodiment of the present invention has a structure in which the display panel 101 having flexibility is partly supported by three support bodies. The electronic device 130 includes a region where the display panel 101 can be bent so that a display surface faces inward (bent inward) and a region where the display panel 101 can be bent so that the display surface faces outward (bent outward). The display panel 101 can also be folded by bending. The electronic device 130 of one embodiment of the present invention has high portability with the display panel 101 folded, and has high browsability of display with a seamless large display region in an opened state.

When the display surface of the display panel 101 is set planar as illustrated in FIG. 8A, a rotation axis 111a of the hinge 103a is provided so as to be positioned on a side opposite to the display surface as in the structure example 2. In addition, at this time, a rotation axis 111b of the hinge 103b is provided so as to be positioned on a display surface side as in the structure example 1.

The support body 102a and the support body 102b can be relatively rotated on the rotation axis 111a of the hinge 103a by an angle greater than or equal to 180° so that the display surface of the display panel 101 becomes convex as in the structure example 2.

The support body 102b and the support body 102c can be relatively rotated on the rotation axis 111b of the hinge 103b by an angle greater than or equal to 180° so that the display surface of the display panel 101 becomes concave as in the structure example 1.

By relatively rotating the support bodies on the rotation axis 111a and the rotation axis 111b, the electronic device 130 can be changed in shape into a folded state illustrated in FIG. 8D through the mode illustrated in FIG. 8C.

As illustrated in FIG. 8D, the support body 102a and the support body 102c can be set parallel to each other by folding the electronic device 130 such that an angle made by facing planes of the support body 102a and the support body 102b and an angle made by facing planes of the support body 102b and the support body 102c are equal to each other. This is preferable because the thickness of the electronic device 130 in the folded state can be uniform.

In addition, the thickness of the electronic device 130 can be reduced by folding the electronic device 130 such that both the above two angles are acute angles as illustrated in FIG. 8D, as compared with the case where the three support bodies are set parallel.

## 14

To use the electronic device 130 of one embodiment of the present invention, the display panel 101 may be opened as illustrated in FIG. 8A so that the entire display surface can be used as a seamless large display surface, or part of the display surface can be used in the folded state as illustrated in FIG. 8D. When the display panel 101 is folded inward, part of the display surface that is hidden from a user is put in a non-display (non-operation) state, leading to a reduction in power consumption of the display panel 101.

Furthermore, only the support body 102a may be rotated to a back side to use part of the display surface overlapping with the support body 102b and the support body 102c. At this time, a portion of the display surface which overlaps with the support body 102a may display an image or the like or may be put in a non-display (non-operation) state. This portion can also be used as a touch pad.

A convexly curved portion of the display surface can display notification of an incoming e-mail, SNS (social networking service), call, or the like; a subject of an e-mail, an SNS, or the like; a sender of an e-mail, an SNS, or the like; the date; the time; remaining battery; the reception strength of an antenna; and the like. Alternatively, an image having a function of an operation button, an icon, a slider, or the like may be displayed.

In addition, the display surface of the display panel 101 is preferably set to have a predetermined aspect ratio in an opened state (e.g., the state illustrated in FIG. 8A). For example, the aspect ratio is set to 9:16 or the like. In addition, the display panel 101 in the folded state (e.g., the state illustrated in FIG. 8D) is preferably set to have a value close to the aspect ratio in the opened state. This enables the aspect ratios of images displayed in the opened and folded states to be substantially equal to each other. Accordingly, in the case where the same image is displayed on the entire display surface visible in the opened and folded states by zooming in or out, generation of an unnatural margin in either state can be reduced.

The above is the description of the structure example 3.

## Structure Example 4

A more specific structure example will be described below. Note that description of portions overlapping with those in the above structure example may be omitted in some cases.

FIG. 9A is a schematic perspective view of an electronic device 140 in a state where the display panel 101 is opened, and FIG. 9B is a schematic perspective view in a state where the display panel 101 is folded.

The electronic device 140 includes the display panel 101, a housing 141, a support body 142a, a support body 142b, a support body 142c, a hinge 143a, and a hinge 143b.

The electronic device 140 can be reversibly changed in shape from the state in FIG. 9A to the state in FIG. 9B by relatively rotating the support bodies on a rotation axis 151a of the hinge 143a and a rotation axis 151b of the hinge 143b.

In addition, the electronic device 140 may include an operation button 145 or the like. For example, the operation button 145 may have a function of switching images displayed on the display surface of the display panel 101, a function of controlling turning on and off power, a function of changing the display panel 101 in shape from the folded state to the opened state, or the like.

FIG. 9C is a schematic cross-sectional view along cutting-plane line G1-G2 illustrated in FIG. 9B. As illustrated in FIG. 9C, the housing 141 includes a printed board 144, a battery 149, and the like in the inside.



## 15

In addition, a plurality of FPCs 147 electrically connected to the display panel 101 are connected to a plurality of terminal connection portions 148 of the printed board 144. Furthermore, power is supplied to the printed board 144 from the battery 149.

As the battery 149, a secondary battery such as a lithium ion battery is preferably used, for example. In addition, the battery 149 preferably includes an antenna and a circuit for controlling charge and discharge and has a wirelessly rechargeable structure.

On the printed board 144, a battery and a variety of ICs such as an arithmetic device and a driver circuit are mounted. Although not illustrated, electronic components, for example, a wireless receiver, a wireless transmitter, a wireless power receiver, and a variety of sensors such as an acceleration sensor are incorporated as appropriate into the housing 141, so that the electronic device 140 can function as a portable terminal, a portable image reproducing device, a portable lighting device, or the like. A camera, a speaker, a variety of input/output terminals such as a power supply terminal and a signal supply terminal, a variety of sensors such as an optical sensor, an operation button, or the like may also be incorporated into the housing 141.

Here, as illustrated in FIG. 9A, the thicknesses of the support body 142b and the support body 142c which do not overlap with the housing 141 in a state where the display panel 101 is opened are preferably small. For example, as illustrated in FIG. 9C, it is preferable that the thicknesses  $t$  of the support body 142b and the support body 142c be equal and smaller than the thickness of the housing 141. For example, the thicknesses  $t$  of the support body 142b and the support body 142c are preferably larger than or equal to 0.3 mm and smaller than or equal to 10 mm, preferably larger than or equal to 0.3 mm and smaller than or equal to 5 mm, and are typically preferably set to 1 mm. By reducing the thicknesses of the support body 142b and the support body 142c, the weight of the electronic device 140 can be reduced, and the portability can be further improved. In addition, when the thicknesses of the support body 142b and the support body 142c are smaller than that of the housing 141, there is a small difference in the position of the center of gravity between the opened and folded states; thus, the use while supporting only the housing 141 with one hand becomes easy in either state, leading to improvement in convenience.

The above is the description of the structure example 4.

## Modification Example

FIG. 10A illustrates a schematic perspective view of an electronic device 160. The electronic device 160 differs mainly in the structures of the housing 141 and the support body 142b in the electronic device 140 exemplified in FIGS. 9A to 9C.

A housing 161 of the electronic device 160 is thinner than the housing 141. Therefore, the electronic device 160 has a structure that is easily graspable with one hand.

In addition, the support body 142b of the electronic device 160 has a mechanism with which the length between both ends thereof changes (also referred to as a slide mechanism) so that a distance between the support body 142a and the support body 142c can be changed.

FIG. 10B illustrates a schematic cross-sectional view of the support body 142b and its vicinity. The support body 142b includes a plate-like member 162a, a plate-like member 162b, a plate-like member 162c, and a screw 163.

## 16

The member 162a is connected to the hinge 143a. The member 162c is connected to the hinge 143b. In addition, the member 162c has an opening 164. The member 162a and the member 162b are provided to overlap with part of the member 162c such that the opening 164 of the member 162c is sandwiched. In addition, the member 162a and the member 162b are fixed to each other by the screw 163. Furthermore, the member 162a and the member 162c as well as the member 162b and the member 162c are not fixed to each other.

With such a structure, the member 162c can be slid with respect to the member 162a and the member 162b in directions of arrows illustrated in the drawing. Therefore, a distance between the hinge 143a and the hinge 143b can be variable. In other words, a distance between the support body 142a and the support body 142c can be changed.

At this time, it is preferable that the display panel 101 be provided so as to be fixed to each of the support body 142a and the support body 142c and not fixed to the support body 142b.

With such a structure, a slight difference in the length of the display panel 101 which is caused by bending the display panel 101 can be corrected by the slide operation of the support body 142b.

In the structure illustrated in FIG. 10B, the length to which the member 162c can be displaced is determined by the position of the screw 163 and the size of the opening 164. In sliding the member 162c, the slide stops when an end portion of the opening 164 is brought into contact with the screw 163.

Note that the structure illustrated in FIGS. 10A and 10B is one example, and any mechanism with which the length between both ends of the support body 142b can be changed is acceptable without limitation to this structure. A mechanism with which the distance between the hinge 143a and the hinge 143b can be changed may be provided in the electronic device 160. Alternatively, a mechanism with which the distance between the support body 142a and the support body 142c can be changed may be provided in the electronic device 160.

At least part of this embodiment can be implemented as appropriate in combination with any of the other embodiments described in this specification.

## Embodiment 2

In this embodiment, structure examples and a manufacturing method example of a light-emitting panel that is applicable to a display panel of the electronic device of one embodiment of the present invention will be described.

## Specific Example 1

FIG. 11A illustrates a plan view of a light-emitting panel, and FIG. 11C illustrates an example of a cross-sectional view along dashed-dotted line A1-A2 in FIG. 11A. The light-emitting panel described in the specific example 1 is a top-emission light-emitting panel using a color filter method. In this embodiment, the light-emitting panel can employ, for example, a structure in which sub-pixels of three colors of R (red), G (green), and B (blue) express one color, or a structure in which sub-pixels of four colors of R (red), G (green), B (blue), and W (white) express one color. There is no particular limitation on a color element, and colors other than R, G, B, and W may be used. For example, yellow, cyan, magenta, and the like may be included.



The light-emitting panel illustrated in FIG. 11A includes a light-emitting portion **804**, driver circuit portions **806**, and an FPC (Flexible Printed Circuit) **808**. Light-emitting elements and transistors included in the light-emitting portion **804** and the driver circuit portions **806** are sealed by a substrate **801**, a substrate **803**, and a sealing layer **823**.

The light-emitting panel illustrated in FIG. 11C includes the substrate **801**, an adhesive layer **811**, an insulating layer **813**, a plurality of transistors, a conductive layer **857**, an insulating layer **815**, an insulating layer **817**, a plurality of light-emitting elements, an insulating layer **821**, the sealing layer **823**, an overcoat **849**, a coloring layer **845**, a light-blocking layer **847**, an insulating layer **843**, an adhesive layer **841**, and the substrate **803**. The sealing layer **823**, the overcoat **849**, the insulating layer **843**, the adhesive layer **841**, and the substrate **803** transmit visible light.

The light-emitting portion **804** includes a transistor **820** and a light-emitting element **830** over the substrate **801** with the adhesive layer **811** and the insulating layer **813** provided therebetween. The light-emitting element **830** includes a lower electrode **831** over the insulating layer **817**, an EL layer **833** over the lower electrode **831**, and an upper electrode **835** over the EL layer **833**. The lower electrode **831** is electrically connected to a source electrode or a drain electrode of the transistor **820**. An end portion of the lower electrode **831** is covered with the insulating layer **821**. The lower electrode **831** preferably reflects visible light. The upper electrode **835** transmits visible light.

The light-emitting portion **804** also includes the coloring layer **845** overlapping with the light-emitting element **830** and the light-blocking layer **847** overlapping with the insulating layer **821**. The coloring layer **845** and the light-blocking layer **847** are covered with the overcoat **849**. A space between the light-emitting element **830** and the overcoat **849** is filled with the sealing layer **823**.

The insulating layer **815** has an effect of reducing the diffusion of impurities into a semiconductor included in the transistor. As the insulating layer **817**, an insulating layer having a planarization function is preferably selected in order to reduce surface unevenness due to the transistor.

The driver circuit portions **806** include a plurality of transistors over the substrate **801** with the adhesive layer **811** and the insulating layer **813** provided therebetween. FIG. 11C illustrates one of the transistors included in the driver circuit portions **806**.

The insulating layer **813** and the substrate **801** are attached to each other with the adhesive layer **811**. In addition, the insulating layer **843** and the substrate **803** are attached to each other with the adhesive layer **841**. It is preferable to use films with low water permeability for the insulating layer **813** and the insulating layer **843**, in which case the entry of an impurity such as water into the light-emitting element **830** or the transistor **820** can be reduced, leading to high reliability of the light-emitting panel.

The conductive layer **857** is electrically connected to an external input terminal through which a signal (e.g., a video signal, a clock signal, a start signal, or a reset signal) or a potential from the outside is transmitted to the driver circuit portion **806**. Here, an example in which the FPC **808** is provided as the external input terminal is described. To prevent an increase in the number of steps, the conductive layer **857** is preferably formed using the same material and the same step as the electrode or the wiring in the light-emitting portion or the driver circuit portion. Here, an example in which the conductive layer **857** is formed using the same material and the same step as the electrodes included in the transistor **820** is described.

In the light-emitting panel illustrated in FIG. 11C, a connector **825** is positioned over the substrate **803**. The connector **825** is connected to the conductive layer **857** through an opening provided in the substrate **803**, the adhesive layer **841**, the insulating layer **843**, the sealing layer **823**, the insulating layer **817**, and the insulating layer **815**. The connector **825** is also connected to the FPC **808**. The FPC **808** and the conductive layer **857** are electrically connected to each other via the connector **825**. In the case where the conductive layer **857** and the substrate **803** overlap with each other, the conductive layer **857**, the connector **825**, and the FPC **808** can be electrically connected to one another by forming an opening in the substrate **803** (or using a substrate having an opening).

The specific example 1 describes the light-emitting panel which can be manufactured by forming the insulating layer **813**, the transistor **820**, and the light-emitting element **830** over a formation substrate with high heat resistance, separating the formation substrate, and transferring the insulating layer **813**, the transistor **820**, and the light-emitting element **830** to the substrate **801** with the adhesive layer **811**. The specific example 1 also describes the light-emitting panel which can be manufactured by forming the insulating layer **843**, the coloring layer **845**, and the light-blocking layer **847** over a formation substrate with high heat resistance, separating the formation substrate, and transferring the insulating layer **843**, the coloring layer **845**, and the light-blocking layer **847** to the substrate **803** with the adhesive layer **841**.

In the case where a material with low heat resistance (e.g., a resin) is used for a substrate, it is difficult to expose the substrate to high temperatures in the manufacturing process. Thus, there is a limitation on conditions for forming a transistor and an insulating layer over the substrate. In addition, in the case where a material with high water permeability (e.g., a resin) is used for a substrate, it is preferable to form a film at high temperatures to have low water permeability. In the manufacturing method of this embodiment, a transistor and the like can be formed over a formation substrate with high heat resistance; thus, a highly reliable transistor and a film with sufficiently low water permeability can be formed at high temperatures. Then, these are transferred to the substrate **801** and the substrate **803**, whereby a highly reliable light-emitting panel can be manufactured. Thus, according to one embodiment of the present invention, a lightweight or thin and highly reliable light-emitting panel can be realized. Details of the manufacturing method will be described later.

#### Specific Example 2

FIG. 11B illustrates a plan view of a light-emitting panel, and FIG. 11D illustrates an example of a cross-sectional view along dashed-dotted line A3-A4 in FIG. 11B. The light-emitting panel described in the specific example 2 is a top-emission light-emitting panel using a color filter method, which is different from that in the specific example 1. Portions different from those in the specific example 1 will be described in detail here and the descriptions of portions common to the specific example 1 will be omitted.

The light-emitting panel illustrated in FIG. 11D is different from the light-emitting panel illustrated in FIG. 11C in the aspects below.

The light-emitting panel illustrated in FIG. 11D includes a spacer **827** over the insulating layer **821**. By providing the spacer **827**, the distance between the substrate **801** and the substrate **803** can be adjusted.



In addition, in the light-emitting panel illustrated in FIG. 11D, the substrate **801** and the substrate **803** have different sizes. The connector **825** is positioned over the insulating layer **843** and thus does not overlap with the substrate **803**. The connector **825** is connected to the conductive layer **857** through an opening provided in the insulating layer **843**, the sealing layer **823**, the insulating layer **817**, and the insulating layer **815**. Since no opening needs to be provided in the substrate **803**, there is no limitation on the material of the substrate **803**.

### Specific Example 3

FIG. 12A illustrates a plan view of a light-emitting panel, and FIG. 12C illustrates an example of a cross-sectional view along dashed-dotted line A5-A6 in FIG. 12A. The light-emitting panel described in the specific example 3 is a top-emission light-emitting panel using a separate coloring method.

The light-emitting panel illustrated in FIG. 12A includes the light-emitting portion **804**, the driver circuit portion **806**, and the FPC **808**. Light-emitting elements and transistors included in the light-emitting portion **804** and the driver circuit portion **806** are sealed by the substrate **801**, the substrate **803**, a frame-like sealing layer **824**, and the sealing layer **823**.

The light-emitting panel illustrated in FIG. 12C includes the substrate **801**, the adhesive layer **811**, the insulating layer **813**, a plurality of transistors, the conductive layer **857**, the insulating layer **815**, the insulating layer **817**, a plurality of light-emitting elements, the insulating layer **821**, the sealing layer **823**, the frame-like sealing layer **824**, and the substrate **803**. The sealing layer **823** and the substrate **803** transmit visible light.

The frame-like sealing layer **824** is preferably a layer having a higher gas barrier property than the sealing layer **823**. Accordingly, the entry of external moisture or oxygen into the light-emitting panel can be reduced. Thus, the light-emitting panel with high reliability can be realized.

In the specific example 3, light emitted from the light-emitting element **830** is extracted from the light-emitting panel through the sealing layer **823**. Therefore, the sealing layer **823** preferably has a higher light-transmitting property than the frame-like sealing layer **824**. In addition, the sealing layer **823** preferably has a higher refractive index than the frame-like sealing layer **824**. In addition, it is preferable that a reduction in the volume of the sealing layer **823** by curing be smaller than that of the frame-like sealing layer **824**.

The light-emitting portion **804** includes the transistor **820** and the light-emitting element **830** over the substrate **801** with the adhesive layer **811** and the insulating layer **813** provided therebetween. The light-emitting element **830** includes the lower electrode **831** over the insulating layer **817**, the EL layer **833** over the lower electrode **831**, and the upper electrode **835** over the EL layer **833**. The lower electrode **831** is electrically connected to the source electrode or the drain electrode of the transistor **820**. The end portion of the lower electrode **831** is covered with the insulating layer **821**. The lower electrode **831** preferably reflects visible light. The upper electrode **835** transmits visible light.

The driver circuit portion **806** includes a plurality of transistors over the substrate **801** with the adhesive layer **811** and the insulating layer **813** provided therebetween. FIG. 12C illustrates one of the transistors included in the driver circuit portion **806**.

The insulating layer **813** and the substrate **801** are attached to each other with the adhesive layer **811**. It is preferable to use a film with low water permeability for the insulating layer **813**, in which case the entry of an impurity such as water into the light-emitting element **830** or the transistor **820** can be reduced, leading to high reliability of the light-emitting panel.

The conductive layer **857** is electrically connected to an external input terminal through which a signal or a potential from the outside is transmitted to the driver circuit portion **806**. Here, an example in which the FPC **808** is provided as the external input terminal is described. In addition, here, an example in which the conductive layer **857** is formed using the same material and the same step as the electrodes included in the transistor **820** is described.

In the light-emitting panel illustrated in FIG. 12C, the connector **825** is positioned over the substrate **803**. The connector **825** is connected to the conductive layer **857** through an opening provided in the substrate **803**, the sealing layer **823**, the insulating layer **817**, and the insulating layer **815**. The connector **825** is also connected to the FPC **808**. The FPC **808** and the conductive layer **857** are electrically connected to each other via the connector **825**.

The specific example 3 describes the light-emitting panel which can be manufactured by forming the insulating layer **813**, the transistor **820**, and the light-emitting element **830** over a formation substrate with high heat resistance, separating the formation substrate, and transferring the insulating layer **813**, the transistor **820**, and the light-emitting element **830** to the substrate **801** with the adhesive layer **811**. A transistor and the like can be formed over a formation substrate with high heat resistance; thus, a highly reliable transistor and a film with sufficiently low water permeability can be formed at high temperatures. Then, these are transferred to the substrate **801**, whereby a highly reliable light-emitting panel can be manufactured. Thus, according to one embodiment of the present invention, a lightweight or thin and highly reliable light-emitting panel can be realized.

### Specific Example 4

FIG. 12B illustrates a plan view of a light-emitting panel, and FIG. 12D illustrates an example of a cross-sectional view along dashed-dotted line A7-A8 in FIG. 12B. The light-emitting panel described in the specific example 4 is a bottom-emission light-emitting panel using a color filter method.

The light-emitting panel illustrated in FIG. 12D includes the substrate **801**, the adhesive layer **811**, the insulating layer **813**, a plurality of transistors, the conductive layer **857**, the insulating layer **815**, a coloring layer **845**, an insulating layer **817a**, an insulating layer **817b**, a conductive layer **816**, a plurality of light-emitting elements, the insulating layer **821**, the sealing layer **823**, and the substrate **803**. The substrate **801**, the adhesive layer **811**, the insulating layer **813**, the insulating layer **815**, the insulating layer **817a**, and the insulating layer **817b** transmit visible light.

The light-emitting portion **804** includes the transistor **820**, a transistor **822**, and the light-emitting element **830** over the substrate **801** with the adhesive layer **811** and the insulating layer **813** provided therebetween. The light-emitting element **830** includes the lower electrode **831** over the insulating layer **817**, the EL layer **833** over the lower electrode **831**, and the upper electrode **835** over the EL layer **833**. The lower electrode **831** is electrically connected to the source electrode or the drain electrode of the transistor **820**. The end portion of the lower electrode **831** is covered with the



insulating layer **821**. The upper electrode **835** preferably reflects visible light. The lower electrode **831** transmits visible light. The position where the coloring layer **845** that overlaps with the light-emitting element **830** is provided is not particularly limited; for example, it may be provided between the insulating layer **817a** and the insulating layer **817b** or between the insulating layer **815** and the insulating layer **817a**.

The driver circuit portion **806** includes a plurality of transistors over the substrate **801** with the adhesive layer **811** and the insulating layer **813** provided therebetween. FIG. 12D illustrates two of the transistors included in the driver circuit portion **806**.

The insulating layer **813** and the substrate **801** are attached to each other with the adhesive layer **811**. It is preferable to use a film with low water permeability for the insulating layer **813**, in which case the entry of an impurity such as water into the light-emitting element **830** or the transistor **820** or **822** can be reduced, leading to high reliability of the light-emitting panel.

The conductive layer **857** is electrically connected to an external input terminal through which a signal or a potential from the outside is transmitted to the driver circuit portion **806**. Here, an example in which the FPC **808** is provided as the external input terminal is described. In addition, here, an example in which the conductive layer **857** is formed using the same material and the same step as the conductive layer **816** is described.

The specific example 4 describes the light-emitting panel which can be manufactured by forming the insulating layer **813**, the transistor **820**, the light-emitting element **830**, and the like over a formation substrate with high heat resistance, separating the formation substrate, and transferring the insulating layer **813**, the transistor **820**, the light-emitting element **830**, and the like to the substrate **801** with the adhesive layer **811**. A transistor and the like can be formed over a formation substrate with high heat resistance; thus, a highly reliable transistor and a film with sufficiently low water permeability can be formed at high temperatures. Then, these are transferred to the substrate **801**, whereby a highly reliable light-emitting panel can be manufactured. Thus, according to one embodiment of the present invention, a lightweight or thin and highly reliable light-emitting panel can be realized.

#### Specific Example 5

FIG. 12E illustrates an example of a light-emitting panel that is different from those in the specific examples 1 to 4.

The light-emitting panel illustrated in FIG. 12E includes the substrate **801**, the adhesive layer **811**, the insulating layer **813**, a conductive layer **814**, a conductive layer **857a**, a conductive layer **857b**, the light-emitting element **830**, the insulating layer **821**, the sealing layer **823**, and the substrate **803**.

The conductive layer **857a** and the conductive layer **857b**, which are external connection electrodes of the light-emitting panel, can each be electrically connected to an FPC or the like.

The light-emitting element **830** includes the lower electrode **831**, the EL layer **833**, and the upper electrode **835**. The end portion of the lower electrode **831** is covered with the insulating layer **821**. The light-emitting element **830** is bottom-emission, top-emission, or dual-emission. An electrode, a substrate, an insulating layer, and the like on the

light extraction side transmit visible light. The conductive layer **814** is electrically connected to the lower electrode **831**.

The substrate on the light extraction side may have, as a light extraction structure, a hemispherical lens, a micro lens array, a film provided with an uneven surface structure, a light diffusing film, or the like. For example, a light extraction structure can be formed by attaching the above lens or film to a resin substrate with an adhesive or the like having substantially the same refractive index as the substrate, or the lens or film.

The conductive layer **814** is preferably, though not necessarily, provided because voltage drop due to the resistance of the lower electrode **831** can be reduced. In addition, for a similar purpose, a conductive layer electrically connected to the upper electrode **835** may be provided over the insulating layer **821**, over the EL layer **833**, over the upper electrode **835**, or the like.

The conductive layer **814** can be a single layer or a stacked layer formed using a material selected from copper, titanium, tantalum, tungsten, molybdenum, chromium, neodymium, scandium, nickel, or aluminum; an alloy material containing any of these as its main component; or the like. The thickness of the conductive layer **814** can be, for example, greater than or equal to 0.1  $\mu\text{m}$  and less than or equal to 3  $\mu\text{m}$ , preferably greater than or equal to 0.1  $\mu\text{m}$  and less than or equal to 0.5  $\mu\text{m}$ .

When a paste (e.g., silver paste) is used as a material for the conductive layer electrically connected to the upper electrode **835**, metal particles forming the conductive layer aggregate. Therefore, the surface of the conductive layer is rough and has many gaps in a structure. Thus, it is difficult for the EL layer **833** to completely cover the conductive layer; accordingly, the upper electrode and the conductive layer are electrically connected to each other easily, which is preferable.

The specific example 5 describes the light-emitting panel which can be manufactured by forming the insulating layer **813**, the light-emitting element **830**, and the like over a formation substrate with high heat resistance, separating the formation substrate, and transferring the insulating layer **813**, the light-emitting element **830**, and the like to the substrate **801** with the adhesive layer **811**. The insulating layer **813** and the like with sufficiently low water permeability are formed over the formation substrate with high heat resistance at high temperatures and then are transferred to the substrate **801**, whereby a highly reliable light-emitting panel can be manufactured. Thus, according to one embodiment of the present invention, a lightweight or thin and highly reliable light-emitting panel can be realized.

#### Examples of Materials

Next, materials and the like that can be used for a light-emitting panel will be described. Note that description on the components already described in this specification may be omitted in some cases.

For each of the substrates, a material such as glass, quartz, an organic resin, a metal, or an alloy can be used. For the substrate on the side from which light from the light-emitting element is extracted, a material which transmits that light is used.

It is particularly preferable to use a flexible substrate. For example, an organic resin or glass, a metal, or an alloy that is thin enough to have flexibility can be used.

An organic resin, which has a specific gravity smaller than that of glass, is preferably used for the flexible substrate, in



which case the light-emitting panel can be more lightweight than in the case where glass is used.

For the substrates, a material with high toughness is preferably used. Accordingly, a light-emitting panel with high impact resistance that is robust can be realized. For example, when an organic resin substrate, a thin metal substrate, or a thin alloy substrate is used, the light-emitting panel which is lighter and more robust than in the case where a glass substrate is used can be realized.

A metal material and an alloy material, which have high thermal conductivity, are preferred because they can easily conduct heat to the whole substrate and accordingly can reduce a local temperature rise in the light-emitting panel. The thickness of a substrate using a metal material or an alloy material is preferably greater than or equal to 10  $\mu\text{m}$  and less than or equal to 200  $\mu\text{m}$ , further preferably greater than or equal to 20  $\mu\text{m}$  and less than or equal to 50  $\mu\text{m}$ .

There is no particular limitation on a material of the metal substrate or the alloy substrate, but it is preferable to use, for example, aluminum, copper, nickel, or a metal alloy such as an aluminum alloy or stainless steel.

Furthermore, when a material with high thermal emissivity is used for the substrate, a surface temperature rise of the light-emitting panel can be reduced, leading to reduction of breakage or a decrease in reliability of the light-emitting panel. For example, the substrate may have a stacked-layer structure of a metal substrate and a layer with high thermal emissivity (e.g., a metal oxide or a ceramic material can be used).

Examples of such a material having flexibility and a light-transmitting property include polyester resins such as polyethylene terephthalate (PET) and polyethylene naphthalate (PEN), a polyacrylonitrile resin, a polyimide resin, a polymethyl methacrylate resin, a polycarbonate (PC) resin, a polyethersulfone (PES) resin, a polyamide resin, a cycloolefin resin, a polystyrene resin, a polyamide imide resin, and a polyvinyl chloride resin. In particular, a material whose coefficient of thermal expansion is low is preferably used, and for example, a polyamide imide resin, a polyimide resin, or PET can be suitably used. A substrate in which a fibrous body is impregnated with a resin (also referred to as prepreg) or a substrate whose coefficient of thermal expansion is reduced by mixing an organic resin with an inorganic filler can also be used.

The flexible substrate may have a stacked-layer structure in which a hard coat layer (such as a silicon nitride layer) by which a device surface is protected from damage or the like, a layer (such as an aramid resin layer) that can disperse pressure, or the like is stacked over a layer of any of the above-mentioned materials.

For the flexible substrate, a plurality of layers may be stacked and used. With a structure including a glass layer, a barrier property against water and oxygen can be improved and thus a reliable light-emitting panel can be provided.

For example, a flexible substrate in which a glass layer, an adhesive layer, and an organic resin layer are stacked from the side closer to a light-emitting element can be used. The thickness of the glass layer is greater than or equal to 20  $\mu\text{m}$  and less than or equal to 200  $\mu\text{m}$ , preferably greater than or equal to 25  $\mu\text{m}$  and less than or equal to 100  $\mu\text{m}$ . With such a thickness, the glass layer can realize both an excellent barrier property against water and oxygen and a high flexibility. The thickness of the organic resin layer is greater than or equal to 10  $\mu\text{m}$  and less than or equal to 200  $\mu\text{m}$ , preferably greater than or equal to 20  $\mu\text{m}$  and less than or equal to 50  $\mu\text{m}$ . By providing such an organic resin layer outside the glass layer, a crack or a break in the glass layer

can be reduced and mechanical strength can be improved. With the substrate that includes such a composite material of a glass material and an organic resin, a highly reliable and flexible light-emitting panel can be provided.

As the adhesive layer or the sealing layer, a variety of curable adhesives such as a reactive curable adhesive, a thermosetting adhesive, an anaerobic adhesive, and a photo curable adhesive such as an ultraviolet curable adhesive can be used. Examples of these adhesives include an epoxy resin, an acrylic resin, a silicone resin, a phenol resin, a polyimide resin, an imide resin, a PVC (polyvinyl chloride) resin, a PVB (polyvinyl butyral) resin, and an EVA (ethylene vinyl acetate) resin. A material with low moisture permeability, such as an epoxy resin, is particularly preferable. Alternatively, a two-component-mixture-type resin may be used. Alternatively, an adhesive sheet or the like may be used.

In addition, the resin may include a drying agent. For example, a substance that adsorbs moisture by chemical adsorption, such as an oxide of an alkaline earth metal (e.g., calcium oxide or barium oxide), can be used. Alternatively, a substance that adsorbs moisture by physical adsorption, such as zeolite or silica gel, may be used. The drying agent is preferably included because it can reduce the entry of an impurity such as moisture into a functional element, thereby improving the reliability of the light-emitting panel.

In addition, by mixing a filler with a high refractive index or light-scattering member into the resin, the efficiency of light extraction from the light-emitting element can be improved. For example, titanium oxide, barium oxide, zeolite, zirconium, or the like can be used.

There is no particular limitation on the structure of the transistors of the light-emitting panel. For example, a staggered transistor or an inverted staggered transistor may be used. Furthermore, the structure of the transistor may be either top-gate or bottom-gate. There is no particular limitation on a semiconductor material used for the transistors; examples include silicon and germanium. Alternatively, an oxide semiconductor containing at least one of indium, gallium, and zinc, such as an In—Ga—Zn-based metal oxide, may be used.

There is no particular limitation on the crystallinity of a semiconductor material used for the transistors, and an amorphous semiconductor or a semiconductor having crystallinity (a microcrystalline semiconductor, a polycrystalline semiconductor, a single crystal semiconductor, or a semiconductor partly including crystal regions) may be used. It is preferable that a semiconductor having crystallinity be used, in which case deterioration of the transistor characteristics can be reduced.

Here, an oxide semiconductor is preferably used for semiconductor devices such as transistors used for pixels, driver circuits, touch sensors described later, or the like. It is particularly preferable to use an oxide semiconductor having a wider band gap than silicon. A semiconductor material having a wider band gap and a lower carrier density than silicon is preferably used because off-state current of the transistor can be reduced.

For example, the oxide semiconductor preferably contains at least at least indium (In) or zinc (Zn). Further preferably, it contains an oxide represented by an In—M—Zn-based oxide (M is a metal such as Al, Ti, Ga, Ge, Y, Zr, Sn, La, Ce, or Hf).

As the semiconductor layer, it is particularly preferable to use an oxide semiconductor film including a plurality of crystal parts whose c-axes are aligned perpendicular to a surface on which the semiconductor layer is formed or the



top surface of the semiconductor layer and in which the adjacent crystal parts have no grain boundary.

There is no grain boundary in such an oxide semiconductor; therefore, generation of a crack in an oxide semiconductor film which is caused by stress when a display panel is curved is reduced. Therefore, such an oxide semiconductor can be preferably used for a display panel which has flexibility and is used in a bent state, or the like.

The use of such materials for the semiconductor layer makes it possible to realize a highly reliable transistor in which a change in the electrical characteristics is reduced.

In addition, charge accumulated in a capacitor through a transistor can be held for a long time because of the low off-state current of the transistor. When such a transistor is used for a pixel, a driver circuit can be stopped while a gray scale of an image displayed in each display region is maintained. As a result, an electronic device with an extremely low power consumption can be realized.

For stable characteristics of the transistor or the like, a base film is preferably provided. The base film can be formed with an inorganic insulating film such as a silicon oxide film, a silicon nitride film, a silicon oxynitride film, or a silicon nitride oxide film to have a single-layer structure or a stacked-layer structure. The base film can be formed using a sputtering method, a CVD (Chemical Vapor Deposition) method (e.g., a plasma CVD method, a thermal CVD method, or an MOCVD (Metal Organic CVD) method), an ALD (Atomic Layer Deposition) method, a coating method, a printing method, or the like. Note that the base film is not necessarily provided when not needed. In each of the above structure examples, the insulating layer **813** can serve as a base film of the transistor.

As the light-emitting element, an element capable of self-emission can be used, and an element whose luminance is controlled by current or voltage is included in its category. For example, a light-emitting diode (LED), an organic EL element, an inorganic EL element, or the like can be used.

The light-emitting element may be top-emission, bottom-emission, or dual-emission. A conductive film that transmits visible light is used as the electrode on the side from which light is extracted. In addition, a conductive film that reflects visible light is preferably used as the electrode on the side from which light is not extracted.

The conductive film that transmits visible light can be formed using, for example, indium oxide, indium tin oxide (ITO: Indium Tin Oxide), indium zinc oxide, zinc oxide, or zinc oxide to which gallium is added. Alternatively, a metal material such as gold, silver, platinum, magnesium, nickel, tungsten, chromium, molybdenum, iron, cobalt, copper, palladium, or titanium; an alloy containing any of these metal materials; or a nitride of any of these metal materials (e.g., titanium nitride) can be used when formed thin so as to have a light-transmitting property. Alternatively, a stacked film of any of the above materials can be used as the conductive layer. For example, a stacked film of ITO and an alloy of silver and magnesium is preferably used, in which case conductivity can be increased. Further alternatively, graphene or the like may be used.

For the conductive film that reflects visible light, for example, a metal material such as aluminum, gold, platinum, silver, nickel, tungsten, chromium, molybdenum, iron, cobalt, copper, or palladium or an alloy containing any of these metal materials can be used. In addition, lanthanum, neodymium, germanium, or the like may be added to the metal material or the alloy. Furthermore, an alloy containing aluminum (an aluminum alloy) such as an alloy of aluminum and titanium, an alloy of aluminum and nickel, or an

alloy of aluminum and neodymium; or an alloy containing silver such as an alloy of silver and copper, an alloy of silver, palladium, and copper, or an alloy of silver and magnesium can be used. An alloy containing silver and copper is preferable because of its high heat resistance. Moreover, a metal film or a metal oxide film is stacked on an aluminum alloy film, whereby oxidation of the aluminum alloy film can be reduced. Examples of a material for the metal film or the metal oxide film include titanium and titanium oxide. Alternatively, the conductive film that transmits visible light and a film containing any of the above metal materials may be stacked. For example, a stacked film of silver and ITO or a stacked film of an alloy of silver and magnesium and ITO can be used.

The electrodes may be formed separately using an evaporation method or a sputtering method. Alternatively, they can be formed using a discharging method such as an ink-jet method, a printing method such as a screen printing method, or a plating method.

When a voltage higher than the threshold voltage of the light-emitting element is applied between the lower electrode **831** and the upper electrode **835**, holes are injected to the EL layer **833** from the anode side and electrons are injected from the cathode side. The injected electrons and holes are recombined in the EL layer **833** and a light-emitting substance contained in the EL layer **833** emits light.

The EL layer **833** includes at least a light-emitting layer. In addition to the light-emitting layer, the EL layer **833** may further include a layer containing a substance with a high hole-injection property, a substance with a high hole-transport property, a hole-blocking material, a substance with a high electron-transport property, a substance with a high electron-injection property, a substance with a bipolar property (a substance with a high electron-transport property and hole-transport property), or the like.

For the EL layer **833**, either a low molecular compound or a high molecular compound can be used, and an inorganic compound may also be contained. Each of the layers included in the EL layer **833** can be formed by a method such as an evaporation method (including a vacuum evaporation method), a transfer method, a printing method, an ink jet method, a coating method, or the like.

The light-emitting element is preferably provided between a pair of insulating films with low water permeability. Thus, the entry of an impurity such as water into the light-emitting element can be reduced, leading to suppression of a decrease in the reliability of the light-emitting device.

Examples of an insulating film with low water permeability include a film containing nitrogen and silicon such as a silicon nitride film or a silicon nitride oxide film, a film containing nitrogen and aluminum such as an aluminum nitride film, and the like. Alternatively, a silicon oxide film, a silicon oxynitride film, an aluminum oxide film, or the like can be used.

For example, the water vapor permeation amount of the insulating film with low water permeability is lower than or equal to  $1 \times 10^{-5}$  [g/(m<sup>2</sup>·day)], preferably lower than or equal to  $1 \times 10^{-6}$  [g/(m<sup>2</sup>·day)], further preferably lower than or equal to  $1 \times 10^{-7}$  [g/(m<sup>2</sup>·day)], still further preferably lower than or equal to  $1 \times 10^{-8}$  [g/(m<sup>2</sup>·day)].

An insulating film with low water permeability is preferably used for the insulating layer **813** and the insulating layer **843**.

As the insulating layer **815**, for example, an inorganic insulating film such as a silicon oxide film, a silicon oxynitride film, or an aluminum oxide film can be used. For



example, as each of the insulating layer **817**, the insulating layer **817a**, and the insulating layer **817b**, an organic material such as polyimide, acrylic, polyamide, polyimide amide, or a benzocyclobutene-based resin can be used. Alternatively, a low-dielectric constant material (a low-k material) or the like can be used. Furthermore, each of the insulating layers may be formed by stacking a plurality of insulating films.

The insulating layer **821** is formed using an organic insulating material or an inorganic insulating material. As the resin, for example, a polyimide resin, a polyamide resin, an acrylic resin, a siloxane resin, an epoxy resin, or a phenol resin can be used. It is particularly preferable that the insulating layer **821** be formed using a photosensitive resin material so that a sidewall thereof has an inclined surface with continuous curvature.

There is no particular limitation on the method for forming the insulating layer **821**; a photolithography method, a sputtering method, an evaporation method, a droplet discharging method (e.g., an ink-jet method), a printing method (e.g., screen printing or off-set printing), or the like may be used.

The spacer **827** can be formed using an inorganic insulating material, an organic insulating material, a metal material, or the like. As the inorganic insulating material and the organic insulating material, for example, a variety of materials that can be used for the insulating layer can be used. As the metal material, titanium, aluminum, or the like can be used. With a structure in which the spacer **827** containing a conductive material and the upper electrode **835** are electrically connected to each other, a potential drop due to the resistance of the upper electrode **835** can be reduced. The spacer **827** may also have either a tapered shape or an inverse tapered shape.

A conductive layer used in the light-emitting panel, which functions as an electrode or a wiring of the transistor, an auxiliary electrode of the light-emitting element, or the like, can be formed to have a single-layer structure or a stacked-layer structure using a metal material such as molybdenum, titanium, chromium, tantalum, tungsten, aluminum, copper, neodymium, or scandium, or an alloy material containing these elements, for example. Alternatively, the conductive layer may be formed using a conductive metal oxide. As the conductive metal oxide, indium oxide (e.g.,  $\text{In}_2\text{O}_3$ ), tin oxide (e.g.,  $\text{SnO}_2$ ), zinc oxide ( $\text{ZnO}$ ), ITO, indium zinc oxide (e.g.,  $\text{In}_2\text{O}_3\text{-ZnO}$ ), or any of these metal oxide materials in which silicon oxide is contained can be used.

The coloring layer is a colored layer that transmits light in a specific wavelength range. For example, a red (R) color filter for transmitting light in a red wavelength range, a green (G) color filter for transmitting light in a green wavelength range, a blue (B) color filter for transmitting light in a blue wavelength range, or the like can be used. Each coloring layer is formed in a desired position with any of various materials by a printing method, an ink-jet method, an etching method using a photolithography method, or the like.

The light-blocking layer is provided between the adjacent coloring layers. The light-blocking layer blocks light from an adjacent light-emitting element to reduce color mixture between adjacent light-emitting elements. Here, the coloring layer is provided such that its end portion overlaps with the light-blocking layer, whereby light leakage can be reduced. As the light-blocking layer, a material that blocks light from the light-emitting element can be used; for example, a black matrix may be formed using a resin material containing a metal material, pigment, or dye. Note that it is preferable to

provide the light-blocking layer in a region other than the light-emitting portion, such as a driver circuit portion, in which case undesired leakage of guided light or the like can be reduced.

Furthermore, an overcoat covering the coloring layer and the light-blocking layer may be provided. With the overcoat, impurities and the like contained in the coloring layer can be prevented from being diffused into the light-emitting element. The overcoat is formed with a material that transmits light emitted from the light-emitting element; for example, an inorganic insulating film such as a silicon nitride film or a silicon oxide film, an organic insulating film such as an acrylic film or a polyimide film can be used, and a stacked-layer structure of an organic insulating film and an inorganic insulating film may be used.

In addition, in the case where a material of the sealing layer is applied onto the coloring layer and the light-blocking layer, a material that has high wettability with respect to the material of the sealing layer is preferably used as the material of the overcoat. For example, an oxide conductive film such as an ITO film or a metal film such as an Ag film that is thin enough to have a light-transmitting property is preferably used as the overcoat.

For the connector, it is possible to use a paste-like or sheet-like material which is obtained by mixing metal particles into a thermosetting resin and for which anisotropic electric conductivity is provided by thermocompression bonding. As the metal particles, particles in which two or more kinds of metals are layered, for example, nickel particles coated with gold are preferably used.

#### Manufacturing Method Example

Next, a method for manufacturing a light-emitting panel is exemplified with reference to FIGS. **13A** to **13C** and FIGS. **14A** to **14C**. Here, description is made using the light-emitting panel having the structure in the specific example 1 (FIG. **11C**) as an example.

First, a separation layer **203** is formed over a formation substrate **201**, and the insulating layer **813** is formed over the separation layer **203**. Next, the plurality of transistors, the conductive layer **857**, the insulating layer **815**, the insulating layer **817**, the plurality of light-emitting elements, and the insulating layer **821** are formed over the insulating layer **813**. Note that an opening is formed in the insulating layer **821**, the insulating layer **817**, and the insulating layer **815** to expose the conductive layer **857** (FIG. **13A**).

In addition, a separation layer **207** is formed over a formation substrate **205**, and the insulating layer **843** is formed over the separation layer **207**. Next, the light-blocking layer **847**, the coloring layer **845**, and the overcoat **849** are formed over the insulating layer **843** (FIG. **13B**).

As each of the formation substrate **201** and the formation substrate **205**, a glass substrate, a quartz substrate, a sapphire substrate, a ceramic substrate, a metal substrate, or the like can be used.

In addition, for the glass substrate, for example, a glass material such as aluminosilicate glass, aluminoborosilicate glass, or barium borosilicate glass can be used. In the case where the temperature of the later heat treatment is high, the one having a strain point of  $730^\circ\text{C}$ . or higher is preferably used. Note that by containing a large amount of barium oxide ( $\text{BaO}$ ), glass which is heat-resistant and more practical can be obtained. Alternatively, crystallized glass or the like may be used.

In the case where a glass substrate is used as the formation substrate, an insulating film such as a silicon oxide film, a



silicon oxynitride film, a silicon nitride film, or a silicon nitride oxide film is preferably formed between the formation substrate and the separation layer, in which case contamination from the glass substrate can be prevented.

Each of the separation layer **203** and the separation layer **207** is a single layer or a stacked layer containing an element selected from tungsten, molybdenum, titanium, tantalum, niobium, nickel, cobalt, zirconium, zinc, ruthenium, rhodium, palladium, osmium, iridium, and silicon; an alloy material containing the element; or a compound material containing the element. A crystal structure of a layer containing silicon may be amorphous, microcrystal, or polycrystal.

The separation layer can be formed by a sputtering method, a plasma CVD method, a coating method, a printing method, or the like. Note that a coating method includes a spin coating method, a droplet discharging method, and a dispensing method.

In the case where the separation layer has a single-layer structure, a tungsten layer, a molybdenum layer, or a layer containing a mixture of tungsten and molybdenum is preferably formed. Alternatively, a layer containing an oxide or an oxynitride of tungsten, a layer containing an oxide or an oxynitride of molybdenum, or a layer containing an oxide or an oxynitride of a mixture of tungsten and molybdenum may be formed. Note that a mixture of tungsten and molybdenum corresponds to an alloy of tungsten and molybdenum, for example.

In the case where the separation layer is formed to have a stacked-layer structure including a layer containing tungsten and a layer containing an oxide of tungsten, the layer containing an oxide of tungsten may be utilized which is formed at the interface between a tungsten layer and an insulating film by forming the layer containing tungsten first and forming an insulating film formed of an oxide thereover. Alternatively, the layer containing an oxide of tungsten may be formed by performing thermal oxidation treatment, oxygen plasma treatment, nitrous oxide (N<sub>2</sub>O) plasma treatment, treatment with a highly oxidizing solution such as ozone water, or the like on the surface of the layer containing tungsten. In addition, plasma treatment or heat treatment may be performed in an atmosphere of oxygen, nitrogen, or nitrous oxide alone, or a mixed gas of the gas and another gas. Surface condition of the separation layer is changed by the plasma treatment or heat treatment, whereby adhesion between the separation layer and the insulating film formed later can be controlled.

Each of the insulating layers can be formed using a sputtering method, a plasma CVD method, a coating method, a printing method, or the like, and can be a dense film with very low water permeability when formed at a deposition temperature higher than or equal to 250° C. and lower than or equal to 400° C. by a plasma CVD method, for example.

Then, a material for the sealing layer **823** is applied to a surface of the formation substrate **205** over which the coloring layer **845** and the like are provided or a surface of the formation substrate **201** over which the light-emitting element **230** and the like are provided, and the formation substrate **201** and the formation substrate **205** are attached so that these surfaces face each other with the sealing layer **823** provided therebetween (FIG. 13C).

Next, the formation substrate **201** is separated, and the exposed insulating layer **813** and the substrate **801** are attached to each other with the adhesive layer **811**. Furthermore, the formation substrate **205** is separated, and the exposed insulating layer **843** and the substrate **803** are

attached to each other with the adhesive layer **841**. Although the substrate **803** does not overlap with the conductive layer **857** in FIG. 14A, the conductive layer **857** and the substrate **803** may overlap with each other.

Note that a variety of methods can be used as appropriate for the separation process. For example, in the case where a layer including a metal oxide film is formed as the separation layer on the side in contact with the layer to be separated, the metal oxide film is embrittled by crystallization, whereby the layer to be separated can be separated from the formation substrate. Alternatively, in the case where an amorphous silicon film containing hydrogen is formed as the separation layer between a formation substrate having high heat resistance and a layer to be separated, the amorphous silicon film is removed by laser light irradiation or etching, whereby the layer to be separated can be separated from the formation substrate. Alternatively, after a layer including a metal oxide film is formed as the separation layer on the side in contact with the layer to be separated, the metal oxide film is embrittled by crystallization, and part of the separation layer is removed by etching using a solution or a fluoride gas such as NF<sub>3</sub>, BrF<sub>3</sub>, or ClF<sub>3</sub>, the separation can be performed at the embrittled metal oxide film. Further alternatively, a method may be employed in which a film containing nitrogen, oxygen, hydrogen, or the like (e.g., an amorphous silicon film containing hydrogen, an alloy film containing hydrogen, or an alloy film containing oxygen) is used as the separation layer, and the separation layer is irradiated with laser light to release the nitrogen, oxygen, or hydrogen contained in the separation layer as gas, thereby promoting separation between the layer to be separated and the substrate. Still further alternatively, it is possible to use a method or the like in which the formation substrate where the layer to be separated is formed is removed mechanically or removed by etching using a solution or a fluoride gas such as NF<sub>3</sub>, BrF<sub>3</sub>, or ClF<sub>3</sub>, or the like. In this case, the separation layer is not necessarily provided.

In addition, when a plurality of the above-described separation methods are combined, the separation process can be performed easily. In other words, separation can be performed with physical force (by a machine or the like) after performing laser light irradiation, etching on the separation layer with a gas, a solution, or the like, or mechanical removal with a sharp knife, scalpel or the like so that the separation layer and the layer to be separated are brought into an easily separable state.

Alternatively, the layer to be separated may be separated from the formation substrate by soaking the interface between the separation layer and the layer to be separated with a liquid. Furthermore, the separation may be performed while a liquid such as water is being poured at the time of separation.

As another separation method, in the case where the separation layer is formed using tungsten, it is preferable that the separation be performed while etching the separation layer using a mixed solution of ammonium water and a hydrogen peroxide solution.

Note that the separation layer is not necessarily provided in the case where separation at an interface between the formation substrate and the layer to be separated is possible. For example, glass is used as the formation substrate, an organic resin such as polyimide, polyester, polyolefin, polyamide, polycarbonate, or acrylic is formed in contact with the glass, and an insulating film, a transistor, and the like are formed over the organic resin. In this case, heating the organic resin enables the separation at the interface between the formation substrate and the organic resin. Alternatively,



separation at the interface between a metal layer and the organic resin may be performed by providing the metal layer between the formation substrate and the organic resin and heating the metal layer by making current to flow in the metal layer.

Lastly, an opening is formed in the insulating layer **843** and the sealing layer **823** to expose the conductive layer **857** (FIG. **14B**). Note that in the case of the structure where the substrate **803** overlaps with the conductive layer **857**, the opening is formed also in the substrate **803** and the adhesive layer **841** so that the conductive layer **857** is exposed (FIG. **14C**). There is no particular limitation on the method for forming the opening. For example, a laser ablation method, an etching method, an ion beam sputtering method, or the like may be used. Alternatively, a cut may be made in a film over the conductive layer **857** with a sharp knife or the like and part of the film may be separated by physical force.

In the above-described manner, the light-emitting panel can be manufactured.

At least part of this embodiment can be implemented as appropriate in combination with any of the other embodiments described in this specification.

### Embodiment 3

In this embodiment, structures of a foldable touch panel that is applicable to a display panel of the electronic device of one embodiment of the present invention will be described with reference to FIGS. **15A** to **15C**, FIGS. **16A** and **16B**, FIGS. **17A** to **17c**, and FIGS. **18A** to **18C**. Note that for a material of each layer, Embodiment 2 can be referred to.

### Structure Example 1

FIG. **15A** is a top view of the touch panel. FIG. **15B** is a cross-sectional view along dashed-dotted line A-B and dashed-dotted line C-D in FIG. **15A**. FIG. **15C** is a cross-sectional view along dashed-dotted line E-F in FIG. **15A**.

As illustrated in FIG. **15A**, a touch panel **390** includes a display portion **301**.

The display portion **301** includes a plurality of pixels **302** and a plurality of imaging pixels **308**. The imaging pixels **308** can sense a touch of a finger or the like on the display portion **301**. Thus, a touch sensor can be formed using the imaging pixels **308**.

The pixels **302** include a plurality of sub-pixels (e.g., a sub-pixel **302R**). In the sub-pixels, light-emitting elements and pixel circuits that can supply electric power for driving the light-emitting elements are provided.

The pixel circuits are electrically connected to wirings through which selection signals can be supplied and wirings through which image signals can be supplied.

Furthermore, the touch panel **390** is provided with a scan line driver circuit **303g(1)** that can supply selection signals to the pixels **302** and an image signal line driver circuit **303s(1)** that can supply image signals to the pixels **302**.

The imaging pixels **308** include photoelectric conversion elements and imaging pixel circuits that drive the photoelectric conversion elements.

The imaging pixel circuits are electrically connected to wirings through which control signals can be supplied and wirings through which power supply potentials can be supplied.

Examples of the control signals include a signal capable of selecting an imaging pixel circuit from which a recorded imaging signal is read, a signal capable of initializing an

imaging pixel circuit, and a signal capable of determining the time it takes for an imaging pixel circuit to sense light.

The touch panel **390** is provided with an imaging pixel driver circuit **303g(2)** that can supply control signals to the imaging pixels **308** and an imaging signal line driver circuit **303s(2)** that reads out imaging signals.

As illustrated in FIG. **15B**, the touch panel **390** includes a substrate **510** and a substrate **570** that faces the substrate **510**.

A flexible material can be favorably used for the substrate **510** and the substrate **570**.

A material with which passage of impurities is reduced can be favorably used for the substrate **510** and the substrate **570**. For example, a material with a water vapor permeability of lower than or equal to  $10^{-5}$  g/(m<sup>2</sup>·day), preferably lower than or equal to  $10^{-6}$  g/(m<sup>2</sup>·day) can be favorably used.

For the substrate **510** and the substrate **570**, materials whose coefficients of linear expansion are substantially equal can be favorably used. For example, materials whose coefficients of linear expansion are lower than or equal to  $1 \times 10^{-3}$ /K, preferably lower than or equal to  $5 \times 10^{-5}$ /K, and further preferably lower than or equal to  $1 \times 10^{-5}$ /K can be favorably used.

The substrate **510** is a stacked body including a flexible substrate **510b**, an insulating layer **510a** that prevents diffusion of impurities into the light-emitting elements, and an adhesive layer **510c** that attaches the flexible substrate **510b** and the insulating layer **510a** to each other.

The substrate **570** is a stacked body including a flexible substrate **570b**, an insulating layer **570a** that prevents diffusion of impurities into the light-emitting elements, and an adhesive layer **570c** that attaches the flexible substrate **570b** and the insulating layer **570a** to each other.

For example, a material that includes polyester, polyolefin, polyamide (e.g., nylon, aramid), polyimide, polycarbonate, or a resin having an acrylic, urethane, epoxy, or siloxane bond can be used for the adhesive layer.

A sealing layer **560** attaches the substrate **570** and the substrate **510** to each other. The sealing layer **560** has a refractive index higher than that of air. In addition, in the case where light is extracted through the sealing layer **560**, the sealing layer **560** also serves as a layer (hereinafter, also referred to as an optical bonding layer) that optically bonds two members (here, the substrate **570** and the substrate **510**) between which the sealing layer **560** is sandwiched. The pixel circuits and the light-emitting elements (e.g., a first light-emitting element **350R**) are provided between the substrate **510** and the substrate **570**.

The pixel **302** includes the sub-pixel **302R**, a sub-pixel **302G**, and a sub-pixel **302B** (FIG. **15C**). In addition, the sub-pixel **302R** includes a light-emitting module **380R**, the sub-pixel **302G** includes a light-emitting module **380G**, and the sub-pixel **302B** includes a light-emitting module **380B**.

For example, the sub-pixel **302R** includes the light-emitting element **350R** and the pixel circuit that can supply electric power to the light-emitting element **350R** and includes a transistor **302t** (FIG. **15B**). Furthermore, the light-emitting module **380R** includes the light-emitting element **350R** and an optical element (e.g., a coloring layer **367R**).

The light-emitting element **350R** includes a lower electrode **351R**, an upper electrode **352**, and an EL layer **353** between the lower electrode **351R** and the upper electrode **352** (FIG. **15C**).



The EL layer **353** includes a first EL layer **353a**, a second EL layer **353b**, and an intermediate layer **354** between the first EL layer **353a** and the second EL layer **353b**.

The light-emitting module **380R** includes the coloring layer **367R** on the substrate **570**. The coloring layer transmits light of a particular wavelength, and for example, the one that selectively transmits light of red, green, blue, or the like can be used. Alternatively, a region that transmits light emitted from the light-emitting element as it is may be provided.

The light-emitting module **380R**, for example, includes the sealing layer **360** that is in contact with the light-emitting element **350R** and the coloring layer **367R**.

The coloring layer **367R** is positioned to overlap with the light-emitting element **350R**. Accordingly, part of light emitted from the light-emitting element **350R** passes through the sealing layer **360** that also serves as an optical bonding layer and through the coloring layer **367R** and is emitted to the outside of the light-emitting module **380R** as indicated by arrows in drawings.

The touch panel **390** includes a light-blocking layer **367BM** on the substrate **570**. The light-blocking layer **367BM** is provided so as to surround the coloring layer (e.g., the coloring layer **367R**).

The touch panel **390** includes an anti-reflective layer **367p** positioned to overlap with the display portion **301**. As the anti-reflective layer **367p**, a circular polarizing plate can be used, for example.

The touch panel **390** includes an insulating layer **321**. The insulating layer **321** covers the transistor **302t**. Note that the insulating layer **321** can be used as a layer for planarizing unevenness caused by the pixel circuits. In addition, an insulating layer on which a layer that can reduce the diffusion of impurities into the transistor **302t** and the like is stacked can be used as the insulating layer **321**.

The touch panel **390** includes the light-emitting elements (e.g., the light-emitting element **350R**) over the insulating layer **321**.

The touch panel **390** includes, over the insulating layer **321**, a partition **328** that overlaps with an end portion of the lower electrode **351R**. In addition, a spacer **329** that controls the distance between the substrate **510** and the substrate **570** is provided over the partition **328**.

The image signal line driver circuit **303s(1)** includes a transistor **303t** and a capacitor **303c**. Note that the driver circuit and the pixel circuits can be formed in the same process over the same substrate. As illustrated in FIG. **15B**, the transistor **303t** may include a second gate **304** over the insulating layer **321**. The second gate **304** may be electrically connected to a gate of the transistor **303t**. Alternatively, different potentials may be supplied thereto. In addition, the second gate **304** may be provided in a transistor **308t**, the transistor **302t**, or the like if necessary.

The imaging pixel **308** includes a photoelectric conversion element **308p** and an imaging pixel circuit for sensing light with which the photoelectric conversion element **308p** is irradiated. In addition, the imaging pixel circuit includes the transistor **308t**.

For example, a pin photodiode can be used as the photoelectric conversion element **308p**.

The touch panel **390** includes a wiring **311** through which a signal can be supplied. The wiring **311** is provided with a terminal **319**. Note that an FPC **309(1)** through which signals such as an image signal and a synchronization signal can be supplied is electrically connected to the terminal **319**. Note that a printed wiring board (PWB) may be attached to the FPC **309(1)**.

Transistors formed in the same process can be used as transistors such as the transistor **302t**, the transistor **303t**, and the transistor **308t**. Embodiment 2 can be referred to for the structures of the transistors.

As a material that can be used for a gate, a source, and a drain of a transistor, and a variety of wirings and electrodes included in a touch panel, a single-layer structure or a stacked-layer structure using a metal such as aluminum, titanium, chromium, nickel, copper, yttrium, zirconium, molybdenum, silver, tantalum, or tungsten, or an alloy containing the same as its main component is used. Examples include a single-layer structure of an aluminum film containing silicon, a two-layer structure in which an aluminum film is stacked over a titanium film, a two-layer structure in which an aluminum film is stacked over a tungsten film, a two-layer structure in which a copper film is stacked over a copper-magnesium-aluminum alloy film, a two-layer structure in which a copper film is stacked over a titanium film, a two-layer structure in which a copper film is stacked over a tungsten film, a three-layer structure in which a titanium film or a titanium nitride film, an aluminum film or a copper film stacked over the titanium film or the titanium nitride film, and a titanium film or a titanium nitride film thereover are formed, a three-layer structure in which a molybdenum film or a molybdenum nitride film, an aluminum film or a copper film stacked over the molybdenum film or the molybdenum nitride film, and a molybdenum film or a molybdenum nitride film thereover are formed, and the like. Note that a transparent conductive material containing indium oxide, tin oxide, or zinc oxide may be used. In addition, copper containing manganese is preferable because controllability of a shape by etching is increased.

#### Structure Example 2

FIGS. **16A** and **16B** are perspective views of a touch panel **505**. Note that main components are illustrated for simplicity. FIGS. **17A** to **17C** are cross-sectional views along dashed-dotted line **X1-X2** illustrated in FIG. **16A**.

The touch panel **505** includes a display portion **501** and a touch sensor **595** (FIG. **16B**). Furthermore, the touch panel **505** includes the substrate **510**, the substrate **570**, and a substrate **590**. Note that the substrate **510**, the substrate **570**, and the substrate **590** each have flexibility.

The display portion **501** includes the substrate **510**, a plurality of pixels over the substrate **510**, and a plurality of wirings **511** through which signals can be supplied to the pixels. The plurality of wirings **511** are led to a peripheral portion of the substrate **510**, and portions thereof form a terminal **519**. The terminal **519** is electrically connected to an FPC **509(1)**.

The substrate **590** includes the touch sensor **595** and a plurality of wirings **598** electrically connected to the touch sensor **595**. The plurality of wirings **598** are led to a peripheral portion of the substrate **590**, and portions thereof form a terminal. The terminal is electrically connected to an FPC **509(2)**. Note that in FIG. **16B**, electrodes, wirings, and the like of the touch sensor **595** provided on the back surface side of the substrate **590** (on the substrate **510** side) are indicated by solid lines for clarity.

As the touch sensor **595**, a capacitive touch sensor can be used, for example. Examples of the capacitive type include a surface capacitive type and a projected capacitive type.

Examples of the projected capacitive type are a self-capacitive type and a mutual capacitive type, which differ



mainly in the driving method. The use of the mutual capacitive type is preferable because multiple points can be detected simultaneously.

A case of using a projected capacitive touch sensor will be described below with reference to FIG. 16B.

Note that a variety of sensors that can sense the approach or contact of a sensing target such as a finger can be used.

The projected capacitive touch sensor 595 includes electrodes 591 and electrodes 592. The electrodes 591 are electrically connected to any of the plurality of wirings 598, and the electrodes 592 are electrically connected to any of the other wirings 598.

The electrodes 592 each have a shape of a plurality of quadrangles arranged in one direction with one corner of a quadrangle connected to one corner of another quadrangle as illustrated in FIGS. 16A and 16B.

The electrodes 591 each have a quadrangular shape and are arranged in a direction intersecting with the direction in which the electrodes 592 extend.

A wiring 594 electrically connects two electrodes 591 between which one electrode 592 is sandwiched. At this time, a shape where the intersecting area of the electrode 592 and the wiring 594 is as small as possible is preferable. This allows a reduction in the area of a region where the electrodes are not provided, reducing unevenness in transmittance. As a result, unevenness in luminance of light transmitted through the touch sensor 595 can be reduced.

Note that the shapes of the electrodes 591 and the electrodes 592 are not limited thereto and can be any of a variety of shapes. For example, the plurality of electrodes 591 may be provided so that spaces therebetween are reduced as much as possible, and a plurality of electrodes 592 may be provided with an insulating layer provided therebetween and may be spaced apart from each other to form a region not overlapping with the electrodes 591. At this time, between two adjacent electrodes 592, a dummy electrode that is electrically insulated from these is preferably provided, whereby the area of a region having a different transmittance can be reduced.

The touch sensor 595 includes the substrate 590, the electrodes 591 and the electrodes 592 provided in a staggered arrangement over the substrate 590, an insulating layer 593 covering the electrodes 591 and the electrodes 592, and the wiring 594 that electrically connects the adjacent electrodes 591 to each other.

An adhesive layer 597 attaches the substrate 590 to the substrate 570 so that the touch sensor 595 overlaps with the display portion 501.

The electrodes 591 and the electrodes 592 are formed using a light-transmitting conductive material. As the light-transmitting conductive material, a conductive oxide such as indium oxide, indium tin oxide, indium zinc oxide, zinc oxide, or zinc oxide to which gallium is added can be used. Note that a film including graphene may be used as well. The film including graphene can be formed, for example, by reducing a film including graphene oxide formed in the form of a film. As a reducing method, a method with application of heat or the like can be employed.

The electrodes 591 and the electrodes 592 may be formed by depositing a light-transmitting conductive material over the substrate 590 by a sputtering method and then removing an unnecessary portion by any of various patterning techniques such as a photolithography method.

As a material that is used for the insulating layer 593, a resin such as acrylic or epoxy, a resin having a siloxane

bond, or an inorganic insulating material such as silicon oxide, silicon oxynitride, or aluminum oxide can also be used.

Furthermore, openings reaching the electrodes 591 are formed in the insulating layer 593, and the wiring 594 electrically connects the adjacent electrodes 591. A light-transmitting conductive material can be favorably used for the wiring 594 because the aperture ratio of the touch panel can be increased. Moreover, a material with higher conductivity than those of the electrodes 591 and the electrodes 592 can be favorably used for the wiring 594 because electric resistance can be reduced.

One of the electrodes 592 extends in one direction, and a plurality of electrodes 592 are provided in the form of stripes.

The wiring 594 is provided so as to intersect with the electrodes 592.

A pair of electrodes 591 are provided with one of the electrodes 592 provided therebetween. The wiring 594 electrically connects the pair of electrodes 591.

Note that the plurality of electrodes 591 are not necessarily arranged in the direction orthogonal to one electrode 592 and may be arranged at an angle of less than 90 degrees.

One wiring 598 is electrically connected to any of the electrodes 591 and the electrodes 592. Part of the wiring 598 serves as a terminal. For the wiring 598, a metal material such as aluminum, gold, platinum, silver, nickel, titanium, tungsten, chromium, molybdenum, iron, cobalt, copper, or palladium or an alloy material containing the metal material can be used.

Note that an insulating layer that covers the insulating layer 593 and the wiring 594 may be provided to protect the touch sensor 595.

Furthermore, a connection layer 599 electrically connects the wiring 598 and the FPC 509(2) to each other.

As the connection layer 599, any of various anisotropic conductive films (ACF: Anisotropic Conductive Film), anisotropic conductive pastes (ACP: Anisotropic Conductive Paste), and the like can be used.

The adhesive layer 597 has a light-transmitting property. For example, a thermosetting resin or an ultraviolet curable resin can be used; specifically, a resin such as acrylic, urethane, epoxy, a resin having a siloxane bond, or the like can be used.

The display portion 501 includes a plurality of pixels arranged in a matrix. The pixel includes a display element and a pixel circuit for driving the display element.

In this embodiment, a case of using an organic EL element that emits white light as a display element will be described; however, the display element is not limited thereto.

For example, organic EL elements that emit light of different colors may be used in sub-pixels so that the light of different colors can be emitted from the respective sub-pixels.

The substrate 510, the substrate 570, and the sealing layer 560 can have structures similar to those in the structure example 1.

A pixel includes a sub-pixel 502R, and the sub-pixel 502R includes a light-emitting module 580R.

The sub-pixel 502R includes a light-emitting element 550R and a pixel circuit including a transistor 502t that can supply electric power to the light-emitting element 550R. Furthermore, the light-emitting module 580R includes the light-emitting element 550R and an optical element (e.g., a coloring layer 567R).



The light-emitting element **550R** includes a lower electrode, an upper electrode, and an EL layer between the lower electrode and the upper electrode.

The light-emitting module **580R** includes the coloring layer **567R** on the light extraction side.

Furthermore, in the case where the sealing layer **560** is provided on the light extraction side, the sealing layer **560** is in contact with the light-emitting element **550R** and the coloring layer **567R**.

The coloring layer **567R** is positioned to overlap with the light-emitting element **550R**. Accordingly, part of light emitted from the light-emitting element **550R** passes through the coloring layer **567R** and is emitted to the outside of the light-emitting module **580R** in a direction of an arrow illustrated in the drawing.

The display portion **501** includes a light-blocking layer **567BM** in the light emitting direction. The light-blocking layer **567BM** is provided so as to surround the coloring layer (e.g., the coloring layer **567R**).

The display portion **501** includes an anti-reflective layer **567p** positioned to overlap with pixels. As the anti-reflective layer **567p**, a circular polarizing plate can be used, for example.

The display portion **501** includes an insulating film **521**. The insulating film **521** covers the transistor **502t**. Note that the insulating film **521** can be used as a layer for planarizing unevenness caused by the pixel circuits. A stacked film including a layer that can reduce the diffusion of impurities can be used as the insulating film **521**. This can suppress a decrease in the reliability of the transistor **502t** or the like by diffusion of impurities.

The display portion **501** includes the light-emitting elements (e.g., the light-emitting element **550R**) over the insulating film **521**.

The display portion **501** includes, over the insulating film **521**, a partition **528** that overlaps with an end portion of a lower electrode. In addition, a spacer that controls the distance between the substrate **510** and the substrate **570** is provided over the partition **528**.

A scan line driver circuit **503g(1)** includes a transistor **503t** and a capacitor **503c**. Note that the driver circuit and the pixel circuits can be formed in the same process over the same substrate.

The display portion **501** includes the wirings **511** through which signals can be supplied. The wirings **511** are provided with the terminal **519**. Note that the FPC **509(1)** through which signals such as an image signal and a synchronization signal can be supplied is electrically connected to the terminal **519**.

Note that a printed wiring board (PWB) may be attached to the FPC **509(1)**.

The display portion **501** includes wirings such as scan lines, signal lines, and power supply lines. The variety of conductive films described above can be used as the wirings.

Note that a variety of transistors can be used in the display portion **501**. A structure in the case of using bottom-gate transistors in the display portion **501** is illustrated in FIGS. **17A** and **17B**.

For example, a semiconductor layer containing an oxide semiconductor, amorphous silicon, or the like can be used in the transistor **502t** and the transistor **503t** illustrated in FIG. **17A**.

For example, a semiconductor layer containing polycrystalline silicon that is obtained by crystallization process such as laser annealing can be used in the transistor **502t** and the transistor **503t** illustrated in FIG. **17B**.

In addition, a structure in the case of using top-gate transistors in the display portion **501** is illustrated in FIG. **17C**.

For example, a semiconductor layer including polycrystalline silicon, a single crystal silicon film that is transferred from a single crystal silicon substrate, or the like can be used in the transistor **502t** and the transistor **503t** illustrated in FIG. **17C**.

### Structure Example 3

FIGS. **18A** to **18C** are cross-sectional views of a touch panel **505B**. The touch panel **505B** described in this embodiment is different from the touch panel **505** in the structure example 2 in including the display portion **501** that displays supplied image data to the side where the transistors are provided and in being provided with the touch sensor on the substrate **510** side of the display portion. Different structures will be described in detail here, and the above description is referred to for portions that can use similar structures.

The coloring layer **567R** is positioned to overlap with the light-emitting element **550R**. In addition, the light-emitting element **550R** illustrated in FIG. **18A** emits light to the side where the transistor **502t** is provided. Accordingly, part of light emitted from the light-emitting element **550R** passes through the coloring layer **567R** and is emitted to the outside of the light-emitting module **580R** in a direction of an arrow illustrated in the drawing.

The display portion **501** includes the light-blocking layer **567BM** in the light emitting direction. The light-blocking layer **567BM** is provided so as to surround the coloring layer (e.g., the coloring layer **567R**).

The touch sensor **595** is provided on the substrate **510** side of the display portion **501** (FIG. **18A**).

The adhesive layer **597** is provided between the substrate **510** and the substrate **590** and attaches the touch sensor **595** and the display portion **501** to each other.

Note that a variety of transistors can be used in the display portion **501**. A structure in the case of using bottom-gate transistors in the display portion **501** is illustrated in FIGS. **18A** and **18B**.

For example, a semiconductor layer containing an oxide semiconductor, amorphous silicon, or the like can be used in the transistor **502t** and the transistor **503t** illustrated in FIG. **18A**.

For example, a semiconductor layer containing polycrystalline silicon or the like can be used in the transistor **502t** and the transistor **503t** illustrated in FIG. **18B**.

In addition, a structure in the case of using top-gate transistors in the display portion **501** is illustrated in FIG. **18C**.

For example, a semiconductor layer including polycrystalline silicon, a transferred single crystal silicon film, or the like can be used in the transistor **502t** and the transistor **503t** illustrated in FIG. **18C**.

At least part of this embodiment can be implemented as appropriate in combination with any of the other embodiments described in this specification.

### Embodiment 4

In this embodiment, an example of a driving method of a touch panel that is applicable to a display panel of the electronic device of one embodiment of the present invention will be described with reference to drawings.

#### Example of Sensing Method of Sensor

FIG. **19A** is a block diagram illustrating the structure of a mutual capacitive touch sensor. FIG. **19A** illustrates a



pulse voltage output circuit **601** and a current detection circuit **602**. Note that in FIG. **19A**, electrodes **621** to which a pulse voltage is applied and electrodes **622** that sense changes in current are denoted by six wirings **X1-X6** and **Y1-Y6**, respectively. In addition, FIG. **19A** also illustrates a capacitor **603** that is formed by an electrode **121** and an electrode **122** overlapping with each other. Note that the functions of the electrode **121** and the electrode **122** may be interchanged with each other.

The pulse voltage output circuit **601** is a circuit for sequentially applying a pulse voltage to the wirings **X1-X6**. By application of a pulse voltage to the wirings **X1-X6**, an electric field is generated between the electrode **121** and the electrode **122** which form the capacitor **603**. By utilizing a change in the mutual capacitance of the capacitor **603** which is caused when the electric field generated between the electrodes is shielded, for example, the approach or contact of a sensing target can be detected.

The current detection circuit **602** is a circuit for detecting changes in current through the wirings **Y1-Y6** that are caused by the change in the mutual capacitance in the capacitor **603**. No change in current value is detected in the wirings **Y1-Y6** when there is no approach or contact of a sensing target, whereas a decrease in current value is detected as a change when mutual capacitance is decreased owing to the approach or contact of a sensing target to be detected. Note that current detection may be performed using an integrator circuit or the like.

Next, FIG. **19B** illustrates a timing chart with input and output waveforms in the mutual capacitive touch sensor illustrated in FIG. **19A**. In FIG. **19B**, detection of a sensing target is performed in all the rows and columns in one frame period. Furthermore, FIG. **19B** illustrates two cases: a case where a sensing target is not detected (not touched) and a case where a sensing target is detected (touched). Note that the waveforms of voltage values corresponding to detected current values are illustrated for the wirings **Y1-Y6**.

A pulse voltage is sequentially applied to the wirings **X1-X6**, and the waveforms of the wirings **Y1-Y6** change in accordance with the pulse voltage. In the case where there is no approach or contact of a sensing target, the waveforms of the **Y1-Y6** uniformly change in accordance with changes in the voltages of the wirings **X1-X6**. Meanwhile, the current value is decreased at the point of approach or contact of a sensing target and accordingly the waveform of the corresponding voltage value also changes.

By detecting a change in mutual capacitance in this manner, the approach or contact of a sensing target can be sensed.

Although FIG. **19A** illustrates a passive-matrix touch sensor in which only the capacitor **603** is provided as a touch sensor at the intersection of wirings, an active-matrix touch sensor including a transistor and a capacitor may also be used. FIG. **20** illustrates an example of a sensor circuit included in an active-matrix touch sensor.

The sensor circuit includes the capacitor **603**, a transistor **611**, a transistor **612**, and a transistor **613**. The transistor **613** has a gate supplied with a signal **G2**, has one of a source and a drain supplied with a voltage **VRES**, and has the other electrically connected to one electrode of the capacitor **603** and a gate of the transistor **611**. The transistor **611** has one of a source and a drain electrically connected to one of a source and a drain of the transistor **612**, and has the other supplied with a voltage **VSS**. The transistor **612** has a gate supplied with a signal **G2**, and has the other of the source

and the drain electrically connected to a wiring **ML**. The other electrode of the capacitor **603** is supplied with the voltage **VSS**.

Next, the operation of the sensor circuit will be described. First, a potential for turning on the transistor **613** is applied as the signal **G2**, and a potential corresponding to the voltage **VRES** is thus applied to a node **n** to which the gate of the transistor **611** is connected. Then, a potential for turning off the transistor **613** is applied as the signal **G2**, and the potential of the node **n** is thus retained.

Then, mutual capacitance of the capacitor **603** changes owing to the approach or contact of a sensing target such as a finger, and accordingly the potential of the node **n** is changed from **VRES**.

In a reading operation, a potential for turning on the transistor **612** is applied as the signal **G1**. A current flowing through the transistor **611**, that is, a current flowing through the wiring **ML** is changed in accordance with the potential of the node **n**. By detecting this current, the approach or contact of a sensing target can be detected.

It is preferable that transistors in which an oxide semiconductor is used for a semiconductor layer where a channel is formed be used as the transistor **611**, the transistor **612**, and the transistor **613**. In particular, by using such a transistor as the transistor **613**, the potential of the node **n** can be retained for a long time and the frequency of operation of resupplying **VRES** to the node **n** (refresh operation) can be reduced.

#### Driving Method Example for Display Device

FIG. **21A** is a block diagram illustrating an example of the structure of a display device. FIG. **21A** illustrates a gate driver circuit **GD**, a source driver circuit **SD**, and pixels **pix**. Note that in FIG. **21A**, the pixels **pix** are denoted by  $(1, 1)$  to  $(n, m)$  which correspond to gate lines  $x_1$  to  $x_m$  ( $m$  is a natural number) electrically connected to the gate driver circuit **GD** and source lines  $y_1$  to  $y_n$  ( $n$  is a natural number) electrically connected to the source driver circuit **SD**.

Next, FIG. **21B** is a timing chart of signals supplied to the gate lines and the source lines in the display device illustrated in FIG. **21A**. The periods in FIG. **21B** show the case where data signals are rewritten every frame period and the case where data signals are not rewritten. Note that periods such as a retrace period are not taken into consideration in FIG. **21B**.

In the case where data signals are rewritten every frame period, scan signals are sequentially supplied to the gate lines  $x_1$  to  $x_m$ . In a horizontal scanning period **1H**, during which the scan signal is at **H** level, data signals **D** are supplied to the source lines  $y_1$  to  $y_n$  in the columns.

In the case where data signals are not rewritten every frame period, the scan signals supplied to the gate lines  $x_1$  to  $x_m$  are stopped. In the horizontal scanning period **1H**, the data signals supplied to the source lines  $y_1$  to  $y_n$  in the columns are stopped.

A driving method in which data signals are not rewritten every frame period is effective particularly in the case where an oxide semiconductor is used for a semiconductor layer where a channel is formed as a transistor included in a pixel. A transistor in which an oxide semiconductor is used can have much lower off-state current than a transistor in which a semiconductor such as silicon is used. Thus, data written in the previous period can be retained without rewriting data



signals every frame period, and the gray levels of pixels can be retained for 1 second or longer, preferably 5 seconds or longer, for example.

#### Example of Driving Method for Display Device and Touch Sensor

FIGS. 22A to 22D are diagrams illustrating examples of the operations in successive frame periods of the touch sensor described with FIGS. 19A and 19B and the display device described with FIGS. 21A and 21B that are driven for 1 sec (one second). Note that FIG. 22A illustrates a case where one frame period for the display device is 16.7 ms (frame frequency: 60 Hz), and one frame period for the touch sensor is 16.7 ms (frame frequency: 60 Hz).

In the touch panel of this embodiment, the display device and the touch sensor operate independently of each other, and a touch sensing period can be concurrent with a display period. That is why one frame periods for the display device and the touch sensor can both be 16.7 ms (frame frequency: 60 Hz) as illustrated in FIG. 22A. The frame frequencies for the touch sensor and the display device may differ from each other. For example, as illustrated in FIG. 22B, one frame period for the display device may be set to 8.3 ms (frame frequency: 120 Hz) and one frame period for the touch sensor may be 16.7 ms (frame frequency: 60 Hz). Although not illustrated, the frame frequency for the display device may also be 33.3 ms (frame frequency: 30 Hz).

The frame frequency for the display device may be changeable, i.e., the frame frequency in displaying moving images may be increased (e.g., 60 Hz or more, or 120 Hz or more), whereas the frame frequency in displaying still images may be decreased (e.g., 60 Hz or less, 30 Hz or less, or 1 Hz or less). Accordingly, power consumption of the display device can be reduced. The frame frequency for the touch sensor may be changeable so that the frame frequencies in waiting and in sensing a touch differ from each other.

In addition, the touch panel of this embodiment retains data rewritten in the previous period without rewriting data signals in the display device, and one frame period for the display device can thus be a period longer than 16.7 ms. Thus, as illustrated in FIG. 22C, one frame period for the display device can be set to 1 sec (frame frequency: 1 Hz) and one frame period for the touch sensor can be 16.7 ms (frame frequency: 60 Hz).

Furthermore, the touch panel of this embodiment can continue to drive the touch sensor in the case of the driving illustrated in FIG. 22C. Thus, data signals in the display device can be rewritten at the timing at which the approach or contact of a sensing target is sensed by the touch sensor, as illustrated in FIG. 22D.

If the operation of rewriting data signals in a display device is performed during a sensing period of a touch sensor, noise caused by driving the display device might be transmitted to the touch sensor, lowering the sensitivity of the touch sensor. For this reason, driving is preferably performed such that a rewriting period for data signals in a display device and a sensing period for a touch sensor are different periods.

FIG. 23A illustrates an example in which rewriting of data signals in a display device and sensing in a touch sensor are performed alternately. In addition, FIG. 23B illustrates an example in which sensing in a touch sensor is performed once every other operation of rewriting data signals in a display device. Note that without being limited thereto, sensing in a touch sensor may be performed once every three or more rewriting operations.

In addition, in the case where an oxide semiconductor is used as a semiconductor where a channel is formed in a transistor used in a pixel of a display device, the off-state current can be significantly reduced and the frequency of rewriting data signals can be sufficiently reduced. Specifically, a sufficiently long break period can be provided after data signal rewriting and before the next data signal rewriting. The break period can be 0.5 seconds or longer, 1 second or longer, or 5 seconds or longer, for example. The upper limit of the break period, which is restricted by the leakage current of a capacitor or a display element connected to a transistor, can be, for example, approximately 1 minute or shorter, 10 minutes or shorter, 1 hour or shorter, or 1 day or shorter.

FIG. 23C illustrates an example in which rewriting of data signals in a display device is performed once every 5 seconds. In FIG. 23C, a break period for stopping the operation of a display device is provided after data signal rewriting and before the next data signal rewriting operation. In the break period, a touch sensor can be driven at a frame frequency of  $i$  Hz ( $i$  is more than or equal to the frame frequency of a display device; here, 0.2 Hz or more). In addition, it is preferable that sensing in a touch sensor be performed in a break period and not be performed in a rewriting period of data signals in a display device as illustrated in FIG. 23C, in which case the sensitivity of the touch sensor can be increased. When rewriting of data signals in a display device and sensing in a touch sensor are performed at the same time as illustrated in FIG. 23D, signals for driving can be simplified.

In a break period during which the operation of rewriting data signals in a display device is not performed, only the supply of signals to a driver circuit may be stopped, and in addition, the supply of a power supply potential may be stopped for further reducing power consumption.

The touch panel of one embodiment of the present invention has a structure in which a display device and a touch sensor are sandwiched between two flexible substrates, for example, and the distance between the display device and the touch sensor can be extremely reduced. At this time, noise caused by driving the display device might be easily transmitted to the touch sensor, lowering the sensitivity of the touch sensor; by employing the driving method exemplified in this embodiment, a touch panel with both reduced thickness and high detection sensitivity can be realized.

#### Embodiment 5

In this embodiment, examples of a structure and a driving method of a touch panel that is applicable to a display panel of the electronic device of one embodiment of the present invention will be described with reference to drawings. [Structure of Touch Panel]

FIG. 24 is a block diagram illustrating a structure example of a touch panel exemplified below. As illustrated in FIG. 24, a touch panel 90 includes a display device 900, a control circuit 910, a counter circuit 920, and a touch sensor 950.

An image signal (Video), which is digital data, and a synchronization signal (SYNC) for controlling rewriting of a screen of the display device 900 are input to the touch panel 90. Examples of the synchronization signal include a horizontal synchronization signal (Hsync), a vertical synchronization signal (Vsync), and a reference clock signal (CLK).

The display device 900 includes a display portion 901, a gate driver 902, and a source driver 903. The display portion 901 includes a plurality of pixels PIX. The pixels PIX in the



same row are connected to the gate driver **902** through a common gate line  $L_X$ , and the pixels  $PIX$  in the same column are connected to the source driver **903** through a common source line  $L_Y$ .

A high-level voltage ( $VH$ ), a low-level voltage ( $VL$ ), and a high power supply voltage ( $VDD$ ) and a low power supply voltage ( $VSS$ ) which serve as power supply voltages are supplied to the display device **900**. The high-level voltage ( $VH$ ) is supplied to each pixel  $PIX$  in the display portion **901** through a wiring  $L_H$ . The low-level voltage ( $VL$ ) is supplied to each pixel  $PIX$  in the display portion **901** through a wiring  $L_L$ .

The source driver **903** processes an input image signal to generate a data signal, and outputs the data signal to the source line  $L_Y$ . The gate driver **902** outputs, to the gate line  $L_X$ , a scan signal for selecting the pixel  $PIX$  into which a data signal is to be written.

The pixel  $PIX$  includes a switching element whose electrical connection to the source line  $L_Y$  is controlled by a scan signal. When the switching element is turned on, a data signal is written into the pixel  $PIX$  through the source line  $L_Y$ .

The control circuit **910** is a circuit that controls the whole touch panel **90** and includes a circuit that generates control signals for circuits included in the touch panel **90**.

The control circuit **910** includes a control signal generation circuit that generates control signals for the gate driver **902** and the source driver **903** from the synchronization signal ( $SYNC$ ). Examples of control signals for the gate driver **902** include a start pulse ( $GSP$ ) and a clock signal ( $GCLK$ ). Examples of control signals for the source driver **903** include a start pulse ( $SSP$ ) and a clock signal ( $SCLK$ ). For example, the control circuit **910** generates a plurality of clock signals with the same cycle and shifted phases as the clock signals ( $GCLK$  and  $SCLK$ ).

In addition, the control circuit **910** controls the output of an image signal ( $Video$ ), which is input from the outside of the touch panel **90** to the source driver **903**.

In addition, a sensor signal ( $S_{touch}$ ) input from the touch sensor **950** is input to the control circuit **910**, and an image signal in accordance with the sensor signal is corrected. The correction of the image signal depends on the sensor signal; image processing corresponding to touch is performed.

The source driver **903** includes a digital/analog conversion circuit **904** (hereinafter referred to as a D-A conversion circuit **904**). The D-A conversion circuit **904** converts an image signal into an analog signal, thereby generating a data signal.

Note that in the case where an image signal input to the touch panel **90** is an analog signal, it is converted into a digital signal in the control circuit **910** and output to the display device **900**.

An image signal is image data for each frame. The control circuit **910** has a function of performing image processing on the image data and controlling output of the image signal to the source driver **903** on the basis of data obtained by the processing. Therefore, the control circuit **910** includes a motion detection portion **911** that performs image processing on the image data to detect motion in accordance with the image data for each frame. Furthermore, in the case where a sensor signal is input, the image signal based on the image data is corrected in response to the sensor signal.

When the motion detection portion **911** determines that there is motion, the control circuit **910** continues to output image signals to the source driver **903**. Conversely, the control circuit **910** stops the output of image signals to the source driver **903** when it is determined that there is no

motion, and restarts the output of image signals when it is determined again that there is motion.

The control circuit **910** can control display in the display portion **901** by switching between a first mode for displaying images with motion (moving image display) and a second mode for displaying images without motion (still image display), depending on determination by the motion detection portion **911**. The first mode is a mode where when the vertical synchronization signal ( $Vsync$ ) is 60 Hz, for example, the frame frequency is set to 60 Hz or higher. The second mode is a mode where when the vertical synchronization signal ( $Vsync$ ) is 60 Hz, for example, the frame frequency is set to lower than 60 Hz.

The frame frequency set in the second mode is preferably set in advance in accordance with a voltage retaining property of a pixel. For example, in the case where the motion detection portion **911** determines that there is no motion for a certain period of time and the output of image signals to the source driver **903** is stopped, a voltage corresponding to the gray level of an image signal that is written to the pixel  $PIX$  is lowered. Therefore, it is preferable to write in a voltage corresponding to the gray level of an image signal for the same image in accordance with the cycle of the frame frequency (also called refreshing). A structure may be employed in which the timing of the refreshing (also referred to as a refresh rate) is performed every certain period of time in accordance with, for example, the vertical synchronization signal (a signal obtained by counting the H level of  $Vsync$ ) in the counter circuit **920**.

In the case where the refresh rate is set to a frequency of once every second with the counter circuit **920**, when the frequency of the vertical synchronization signal ( $Vsync$ ) is 60 Hz, refresh may be performed in response to a count signal ( $Count$ ) that is obtained by counting the H level of the vertical synchronization signal ( $Vsync$ ) to 60. In the case where the refresh rate is set to a frequency of once every five seconds, when the frequency of the vertical synchronization signal ( $Vsync$ ) is 60 Hz, refresh may be performed in response to a count signal ( $Count$ ) that is obtained by counting the H level of the vertical synchronization signal ( $Vsync$ ) to 300. Furthermore, in the case where a sensor signal input from the touch sensor **950** is input, the counter circuit **920** may be configured to forcibly switch from the second mode to the first mode in response to the sensor signal.

Note that there is no particular limitation on the image processing for detecting motion that is performed in the motion detection portion **911**. An example of a method for detecting motion is a method to obtain difference data from image data for two consecutive frames, for example. It can be determined whether there is motion or not from the obtained difference data. There is also a method to detect a motion vector or the like.

The operation and structure described in the above embodiment can be used for the touch sensor **950**.

The display device and the touch sensor **950** of this embodiment can be operated independently of each other; thus, a touch sensing period concurrent with a display period can be provided. Even in the structure in which the control circuit **910** switches between the first mode and the second mode, the operation of the touch sensor can thus be controlled independently. By synchronizing the operation of the display device **900** with that of the touch sensor **950** and performing the operation of rewriting data signals in the display device **900** and the sensing operation in the touch sensor **950** in different periods, the sensitivity of sensing can be increased.



FIG. 25A is a circuit diagram illustrating a structure example of the pixel PIX. The pixel PIX includes a transistor TR1, a transistor TR2, a light-emitting element EL, and a capacitor CAP.

The transistor TR1 functions as a switching element that controls electrical connection between the source line L\_Y and a gate of the transistor TR1, and whether it is turned on or off is controlled by a scan signal input to its gate. The transistor TR2 functions as a switching element for controlling a current supplied to the light-emitting element EL.

Note that an oxide semiconductor is preferably used for a semiconductor where a channel is formed in the transistor TR1 and the transistor TR2.

The light-emitting element EL includes an EL layer containing a light-emitting organic compound sandwiched between two electrodes. The luminance of light emitted from the light-emitting element depends on a current flowing between the two electrodes. A low-level potential is applied from the wiring L\_L to one electrode of the light-emitting element, and a high-level potential is applied from the wiring L\_H to the other electrode via the transistor TR2.

The capacitor Cap has a function of retaining the potential of the gate of the transistor TR2.

FIG. 25B is an example of the pixel PIX including a liquid crystal element. The pixel PIX includes a transistor TR, a liquid crystal element LC, and a capacitor CAP.

The transistor TR is a switching element that controls electrical connection between one electrode of the liquid crystal element LC and the source line L\_Y, and whether it is turned on or off is controlled by a scan signal input to its gate.

Note that an oxide semiconductor is preferably used as a semiconductor where a channel is formed in the transistor TR.

The liquid crystal element LC includes two electrodes and a liquid crystal. The alignment of the liquid crystal is changed by the action of an electric field between the two electrodes. One of the two electrodes of the liquid crystal element LC, which is connected to the source line L\_Y through the transistor TR, corresponds to a pixel electrode, and the other, which is connected to a common line L\_com to which Vcom is applied, corresponds to a common electrode.

The capacitor Cap is connected in parallel with the liquid crystal element LC. In this case, one electrode of the capacitor is connected to a source or a drain of the transistor TR, and the other electrode of the capacitor is connected to a capacitor line L\_cap to which a capacitor line voltage is applied.

Note that although the example where the liquid crystal element LC or the light-emitting element EL is used as a display element is described here, one embodiment of the present invention is not limited thereto.

In this specification and the like, for example, a display element, a display device which is a device including a display element, a light-emitting element, and a light-emitting device which is a device including a light-emitting element can employ a variety of modes or can include a variety of elements. The display element, the display device, the light-emitting element, or the light-emitting device includes at least one of an EL (electroluminescence) element (e.g., an EL element including organic and inorganic materials, an organic EL element, or an inorganic EL element), an LED (e.g., a white LED, a red LED, a green LED, or a blue LED), a transistor (a transistor that emits light depending on

current), an electron emitter, a liquid crystal element, electronic ink, an electrophoretic element, a grating light valve (GLV), a plasma display panel (PDP), a display element using MEMS (micro electro mechanical system), a digital micromirror device (DMD), a DMS (digital micro shutter), MIRASOL (registered trademark), an interferometric modulator (IMOD) element, a MEMS shutter display element, an optical-interference-type MEMS display element, an electrowetting element, a piezoelectric ceramic display, a display element including a carbon nanotube, and the like. Other than the above, a display medium whose contrast, luminance, reflectance, transmittance, or the like is changed by electrical or magnetic action may be included. Examples of a display device including an EL element include an EL display. Examples of a display device including an electron emitter include a field emission display (FED) and an SED-type flat panel display (SED: Surface-conduction Electron-emitter Display). Examples of a display device including a liquid crystal element include a liquid crystal display (a transmissive liquid crystal display, a transreflective liquid crystal display, a reflective liquid crystal display, a direct-view liquid crystal display, or a projection liquid crystal display). Examples of a display device including electronic ink or an electrophoretic element include electronic paper.

Note that in the case of realizing a transreflective liquid crystal display or a reflective liquid crystal display, some or all of pixel electrodes may function as reflective electrodes. For example, some or all of pixel electrodes are formed to contain aluminum, silver, or the like. In such a case, a memory circuit such as an SRAM can be further provided under the reflective electrodes. Accordingly, power consumption can be further reduced.

For example, in this specification and the like, an active-matrix method in which an active element (a non-linear element) is included in a pixel or a passive-matrix method in which an active element is not included in a pixel can be used.

In the active-matrix method, as an active element, not only a transistor but also a variety of active elements can be used. For example, an MIM (Metal Insulator Metal), a TFD (Thin Film Diode), or the like can also be used. Since these elements can be formed with a smaller number of manufacturing steps, manufacturing cost can be reduced or yield can be improved. Alternatively, since the size of these elements is small, the aperture ratio can be improved, so that power consumption can be reduced or higher luminance can be achieved.

Since an active element is not used in the passive-matrix type, the number of manufacturing steps is small, so that manufacturing cost can be reduced or yield can be improved. Alternatively, since an active element is not used, the aperture ratio can be improved, so that power consumption can be reduced or higher luminance can be achieved, for example.

#### Driving Method Example for Touch Panel

The operation of the touch panel 90, which performs display in the first mode for moving image display and in the second mode for still image display, will be described below with reference to a timing chart in FIG. 26. FIG. 26 illustrates the signal waveforms of the vertical synchronization signal (Vsync) and a data signal (Vdata) that is output to the source line L\_Y from the source driver 903.

FIG. 26 is an example of a timing chart of the touch panel 90 in the case where moving image display, still image display, and moving image display are performed in that



order. Here, there is motion in image data for the first to k-th frames. Then, there is no motion in image data for the (k+1)-th to (k+3)-th frames. Then, there is motion in image data for the (k+4)-th and subsequent frames. Note that k is an integer of 2 or more.

In the first moving image display period, the motion detection portion **911** determines that there is motion in image data for each frame. Therefore, the touch panel **90** operates in the first mode. The control circuit **910** outputs image signals (Video) to the source driver **903** at higher than or equal to the frequency of the vertical synchronization signal, here a frame frequency  $f_1$ . The source driver **903** continuously outputs data signals (Vdata) to the source line L\_Y. Note that the length of one frame period in the moving image display period is represented by  $1/f_1$  (seconds).

Next, in the still image display period, the motion detection portion **911** performs image processing for detecting motion and determines that there is no motion in image data for the (k+1)-th frame. Therefore, the touch panel **90** operates in the second mode. The control circuit **910** outputs to the source driver **903** at a frame frequency lower than the frequency of the vertical synchronization signal, here a frame frequency  $f_2$ . The source driver **903** intermittently outputs data signals (Vdata) to the source line L\_Y. Note that the length of one frame period in the still image display period is represented by  $1/f_2$  (seconds).

Since the source driver **903** can intermittently output data signals (Vdata), the supply of control signals (e.g., a start pulse signal and a clock signal) to the gate driver **902** and the source driver **903** can also be performed intermittently; thus, the gate driver **902** and the source driver **903** can be stopped at regular intervals.

The intermittent output of data signals (Vdata) to the source line L\_Y in the second mode will be specifically described. For example, as illustrated in FIG. 26, in the (k+1)-th frame, the control circuit **910** outputs control signals to the gate driver **902** and the source driver **903** and outputs image signals Video to the source driver **903** at the frame frequency  $f_2$ . The source driver **903** outputs the data signal (Vdata) written in the previous period, that is, the data signal (Vdata) output to the source line L\_Y in the k-th frame, to the source line L\_Y. In this manner, in the still image display period, the data signal (Vdata) written in the previous period is repeatedly written to the source line L\_Y every period of  $1/f_2$  (seconds). Thus, a voltage corresponding to the gray level of an image signal for the same image can be refreshed. Refresh performed at regular intervals can reduce flickers due to the shift of gray levels caused by a voltage drop and can provide a touch panel with improved display quality.

The control circuit **910** operates in the second mode until the result of determination that there is motion in image data or the input of a sensor signal is obtained in the motion detection portion **911**.

Then, when the motion detection portion **911** determines that there is motion in image data for the (k+4)-th and subsequent frames, the touch panel **90** operates in the first mode again. The control circuit **910** outputs image signals (Video) to the source driver **903** at higher than or equal to the frequency of the vertical synchronization signal, here the frame frequency  $f_1$ . The source driver **903** continuously outputs data signals (Vdata) to the source line L\_Y.

The touch panel of one embodiment of the present invention has a structure in which a display device and a touch sensor are sandwiched between two flexible substrates, for example, and the distance between the display device and the touch sensor can be extremely reduced. At this time,

noise caused by driving the display device might be easily transmitted to the touch sensor, lowering the sensitivity of the touch sensor; by employing the driving method exemplified in this embodiment, a touch panel with both reduced thickness and high detection sensitivity can be realized.

At least part of this embodiment can be implemented as appropriate in combination with any of the other embodiments described in this specification.

### Example

In this example, an electronic device of one embodiment of the present invention was manufactured.

A display panel of the electronic device manufactured in this example was manufactured by forming a separation layer (a tungsten film) over a formation substrate (a glass substrate), forming a layer to be separated which included a transistor, a light-emitting element, and the like over the separation layer, then separating the formation substrate and the layer to be separated from each other, and attaching a flexible substrate to the separated layer with an adhesive.

As the transistor, a transistor using a CAAC-OS (C Axis Aligned Crystalline Oxide Semiconductor) was used. Unlike an amorphous one, the CAAC-OS has few defect states and can improve the reliability of the transistor. Moreover, since the CAAC-OS is characterized in that a grain boundary is not observed, a stable and uniform film can be formed over a large area and stress that is caused by curving a flexible light-emitting device does not easily make a crack in a CAAC-OS film.

The CAAC-OS refers to a crystalline oxide semiconductor having c-axis alignment of crystals in a direction substantially perpendicular to the film surface. It has been confirmed that oxide semiconductors have a variety of crystal structures other than a single crystal, for example, a nano-crystal (nc), which is an aggregate of nanoscale micro-crystals. The crystallinity of the CAAC-OS is lower than that of a single crystal and higher than that of an nc.

In this example, a channel-etched transistor using an In—Ga—Zn-based oxide was used. The transistor was manufactured over a glass substrate through a process at lower than 500° C.

In a method of manufacturing an element such as a transistor directly over an organic resin such as a plastic substrate, the temperature of the process for manufacturing the element needs to be lower than the upper temperature limit of the organic resin. In this example, the formation substrate is a glass substrate and the separation layer, which is an inorganic film, has high heat resistance; thus, the transistor can be manufactured at the same temperature as in the case where a transistor is manufactured over a glass substrate, and the performance and reliability of the transistor can be easily secured.

As the light-emitting element, a white-light-emitting tandem (stacked) organic EL element was used. The light-emitting element has a top-emission structure, and light from the light-emitting element is extracted to the outside of the display panel through a color filter.

In the manufactured display panel, the diagonal size of a display portion is 5.9 inches, the number of pixels is 720×1280, the pixel size is 102 μm×102 μm, the resolution is 249 ppi, and the aperture ratio is 45.2%. In addition, the frame frequency is 60 Hz, a scan driver was integrated, and a source driver was mounted by a COF method. The manufactured display panel had a thickness of 100 μm or less and a weight of approximately 3 g.



FIGS. 27A, 27B, and 27C show photographs of the manufactured electronic device. FIG. 27A shows a state where a display surface of the display panel is planar, FIG. 27B shows a state in the middle of folding the display panel, and FIG. 27C shows a state where the display panel is folded. Note that reference numerals and the like are omitted in FIGS. 27B and 27C for clarity.

The electronic device shown in FIG. 27A and the like includes the display panel 101, the support body 142a, the support body 142b, the support body 142c, the hinge 143a, and the hinge 143b. In addition, the support body 142b has a mechanism with which the length between both ends thereof changes (a slide mechanism 165).

In this manner, the electronic device of one embodiment of the present invention can be easily changed in shape from the state where the display surface of the display panel 101 is planar into the state where it is folded without damage to the display panel 101.

The above is the description of the example.

At least part of this example can be implemented as appropriate in combination with any of the embodiments described in this specification.

#### REFERENCE NUMERALS

100 electronic device  
 101 display panel  
 101a portion  
 101b portion  
 101c portion  
 102a support body  
 102b support body  
 102c support body  
 103 hinge  
 103a hinge  
 103b hinge  
 110 hinge  
 110a plane  
 110b plane  
 111 rotation axis  
 111a rotation axis  
 111b rotation axis  
 120 electronic device  
 121 electrode  
 122 electrode  
 130 electronic device  
 140 electronic device  
 141 housing  
 142a support body  
 142b support body  
 142c support body  
 143a hinge  
 143b hinge  
 144 printed board  
 145 operation button  
 147 FPC  
 148 terminal connection portion  
 149 battery  
 151a rotation axis  
 151b rotation axis  
 160 electronic device  
 161 housing  
 162a member  
 162b member  
 162c member  
 163 screw  
 164 opening

201 formation substrate  
 203 separation layer  
 205 formation substrate  
 207 separation layer  
 5 230 light-emitting element  
 301 display portion  
 302 pixel  
 302B sub-pixel  
 302G sub-pixel  
 10 302R sub-pixel  
 302t transistor  
 303c capacitor  
 303g(1) scan line driver circuit  
 303g(2) imaging pixel driver circuit  
 15 303s(1) image signal line driver circuit  
 303s(2) imaging signal line driver circuit  
 303t transistor  
 304 gate  
 308 imaging pixel  
 20 308p photoelectric conversion element  
 308t transistor  
 309 FPC  
 311 wiring  
 319 terminal  
 25 321 insulating layer  
 328 partition  
 329 spacer  
 350R light-emitting element  
 351R lower electrode  
 30 352 upper electrode  
 353 EL layer  
 353a EL layer  
 353b EL layer  
 354 intermediate layer  
 35 360 sealing layer  
 367BM light-blocking layer  
 367p anti-reflective layer  
 367R coloring layer  
 380B light-emitting module  
 40 380G light-emitting module  
 380R light-emitting module  
 390 touch panel  
 501 display portion  
 502R sub-pixel  
 45 502t transistor  
 503c capacitor  
 503g scan line driver circuit  
 503t transistor  
 505 touch panel  
 50 505B touch panel  
 509 FPC  
 510 substrate  
 510a insulating layer  
 510b flexible substrate  
 55 510c adhesive layer  
 511 wiring  
 519 terminal  
 521 insulating film  
 528 partition  
 60 550R light-emitting element  
 560 sealing layer  
 567BM light-blocking layer  
 567p anti-reflective layer  
 567R coloring layer  
 65 570 substrate  
 570a insulating layer  
 570b flexible substrate



**570c** adhesive layer  
**580R** light-emitting module  
**590** substrate  
**591** electrode  
**592** electrode  
**593** insulating layer  
**594** wiring  
**595** touch sensor  
**597** adhesive layer  
**598** wiring  
**599** connection layer  
**601** pulse voltage output circuit  
**602** current detection circuit  
**603** capacitor  
**611** transistor  
**612** transistor  
**613** transistor  
**621** electrode  
**622** electrode  
**801** substrate  
**803** substrate  
**804** light-emitting portion  
**806** driver circuit portion  
**808** FPC  
**811** adhesive layer  
**813** insulating layer  
**814** conductive layer  
**815** insulating layer  
**816** conductive layer  
**817** insulating layer  
**817a** insulating layer  
**817b** insulating layer  
**820** transistor  
**821** insulating layer  
**822** transistor  
**823** sealing layer  
**824** sealing layer  
**825** connector  
**827** spacer  
**830** light-emitting element  
**831** lower electrode  
**833** EL layer  
**835** upper electrode  
**841** adhesive layer  
**843** insulating layer  
**845** coloring layer  
**847** light-blocking layer  
**849** overcoat  
**857** conductive layer  
**857a** conductive layer  
**857b** conductive layer  
**90** touch panel  
**900** display device  
**901** display portion  
**902** gate driver  
**903** source driver  
**904** D-A conversion circuit  
**910** control circuit  
**911** detection portion  
**920** counter circuit  
**950** touch sensor

This application is based on Japanese Patent Application serial no. 2014-039372 filed with Japan Patent Office on Feb. 28, 2014 and Japanese Patent Application serial no. 2014-218932 filed with Japan Patent Office on Oct. 28, 2014, the entire contents of which are hereby incorporated by reference.

What is claimed is:

1. A display device comprising:
  - a display panel having flexibility;
  - a first support body and a second support body each supporting the display panel; and
  - a pair of connections connecting the first support body and the second support body to each other,
 wherein:
  - the display panel comprises a first portion supported by the first support body, a second portion supported by the second support body, and a third portion between the first portion and the second portion,
  - the pair of connections have a rotation axis,
  - the first support body with the first portion are configured to rotate on the rotation axis,
  - the second support body with the second portion are configured to rotate on the rotation axis,
  - a distance between the first portion and the rotation axis is greater than zero,
  - a distance between the second portion and the rotation axis is greater than zero,
  - when an angle from a state where the first and second support bodies are horizontal is 0 degree, the rotation axis is located on a front surface side of the third portion, and
  - when an angle from the state is 180 degrees, the rotation axis is located on a back surface side of the third portion.
2. The display device according to claim 1, wherein the display panel is foldable so that an end portion of the first support body is in contact with an end portion of the second support body.
3. The display device according to claim 1, wherein a distance between the third portion and the rotation axis is greater than zero, when the first support body and the second support body are horizontal or an end portion of the first support body is in contact with an end portion of the second support body.
4. The display device according to claim 1, wherein:
  - the display panel comprises a display surface overlapping with the first portion, the second portion and the third portion,
  - the rotation axis and a first plane including the display surface overlapping with the first portion are parallel to each other, and
  - the rotation axis and a second plane including the display surface overlapping with the second portion are parallel to each other.
5. The display device according to claim 1, wherein the distance between the first portion and the rotation axis and the distance between the second portion and the rotation axis are substantially equal to each other.
6. The display device according to claim 1, wherein the first support body and the second support body are capable of rotating on the rotation axis by an angle greater than 180 degrees from the state.
7. The display device according to claim 1, wherein the display panel comprises a module including a touch sensor provided on a surface of the display panel.
8. A display device comprising:
  - a display panel having flexibility;
  - a first support body, a second support body, and a third support body each supporting the display panel;
  - a pair of first connections connecting the first support body and the second support body to each other; and
  - a pair of second connections connecting the second support body and the third support body to each other,



wherein:

the display panel comprises a first portion supported by the first support body, a second portion supported by the second support body, a third portion supported by the third support body, a fourth portion between the first portion and the second portion, and a fifth portion between the second portion and the third portion, the pair of first connections have a first rotation axis, the pair of second connections have a second rotation axis, each of the first support body with the first portion and the second support body with the second portion is configured to rotate on the first rotation axis, each of the third support body with the third portion and the second support body with the second portion is configured to rotate on the second rotation axis, a distance between the first portion and the first rotation axis is greater than zero, a distance between the second portion and the first rotation axis is greater than zero, a distance between the third portion and the second rotation axis is greater than zero, a distance between the second portion and the second rotation axis is greater than zero, when an angle from a first state where the first and second support bodies are horizontal is 0 degree, the first rotation axis is located on a front surface side of the fourth portion, and when an angle from the first state is 180 degrees, the first rotation axis is located on a back surface side of the fourth portion.

9. The display device according to claim 8, wherein the display panel is foldable so that an end portion of the first support body is in contact with one of end portions of the second support body and/or an end portion of the third support body is in contact with the other of end portions of the second support body.

10. The display device according to claim 8, wherein: a distance between the fourth portion and the first rotation axis is greater than zero, when the first support body and the second support body are horizontal or an end portion of the first support body is in contact with one of end portions of the second support body, and a distance between the fifth portion and the second rotation axis is greater than zero, when the third support body and the second support body are horizontal or an

end portion of the first support body is in contact with the other of end portions of the second support body.

11. The display device according to claim 8, wherein: the display panel comprises a display surface overlapping with the first portion, the second portion, the third portion, the fourth portion and the fifth portion, wherein the first rotation axis and a first plane including the display surface overlapping with the first portion are parallel to each other, wherein the first rotation axis and a second plane including the display surface overlapping with the second portion are parallel to each other, wherein the second rotation axis and a third plane including the display surface overlapping with the third portion are parallel to each other, and wherein the second rotation axis and the second plane are parallel to each other.

12. The display device according to claim 8, wherein: the distance between the first portion and the first rotation axis and the distance between the second portion and the first rotation axis are substantially equal to each other, and the distance between the second portion and the second rotation axis and the distance between the third portion and the second rotation axis are substantially equal to each other.

13. The display device according to claim 8, wherein: the first support body and the second support body are capable of rotating on the first rotation axis by an angle greater than 180 degrees from the first state, and the second support body and the third support body are capable of rotating on the second rotation axis by an angle greater than 180 degrees from a second state where the second support body and the third support body are horizontal.

14. The display device according to claim 8, wherein the display panel comprises a module including a touch sensor provided on a surface of the display panel.

15. The display device according to claim 1, wherein the third portion is in contact with the first and second support bodies on the back surface side in the state.

16. The display device according to claim 8, wherein the fourth portion is in contact with the first and second support bodies on the back surface side in the first state.

\* \* \* \* \*